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Section I

JOINT FRACTURES AND DISLOCATIONS

1

Nicolas Andry, Founder of the Orthopaedic Specialty

H WINNETT ORR, M D

The "Orthos Pais" or great seal of the American Orthopaedic Association (Fig. 1) and the emblem of the crooked tree being straightened by a splint, used by the British in their Presidential Badge of Office for the American Presidents at the London meeting in 1953 (Fig 2) are tributes to Nicolas Andry (1658 1742) who published the first book on orthopaedic surgery in 1741[3] (Figs 3 and 4)

Other than these tributes Andry has had too little recognition, either for his broad view or for his conception of the details necessary for the proper care of the crippled child.[14 15] Andry is so little known as a person that his name often is misspelled "André," the name of a later French surgeon who is distinguished for having "patented" some catheters and urethral bougies and for a text on diseases of the ureter Andry was a historian (a characteristic of all sound innovators) a writer and an official high in the councils of the medical scholars in Paris.

Andry said of the title of his *L orthopédie*

> As to the Title I have formed it of two Greek Words, *viz.* Orthos, which signifies streight [sic] free from Deformity and Pais a Child. Out of these two Words I have compounded that of Orthopaedia, to express in one Term the Design I propose which is to teach the different Methods of preventing and correction the Deformities of Children.[2]

In the English edition the spelling was changed from the French "orthopédie" to "orthopaedia," presumably to avoid the "pedis" (foot) connotation In his very useful *Source Book of Orthopaedics* Bick spelled the name "André" and took the title from the English edition. However Andry of course was presented correctly in every other way in Bick s text.[6]

HISTORICAL SURVEY

Andry s preoccupation with muscular contraction as a cause of deformity influenced nearly all of the French orthopaedic specialists who followed him In fact, one might suppose that the great John Hunter got some of his ideas which he elaborated so well from Andry s work, published when Hunter was 13 years old.[12] Because of his special interest in the muscular system, Andry was led at once to the use of exercises and good posture in his prophylactic and curative expedients In this way he undoubtedly influenced Venel, Delpech,[8] Ling and perhaps Hunter[17] the extent of Andry s influence cannot be measured easily but there are indirect evidences that it might have been considerable

The great orthopaedic biographer Sir Arthur Keith, somewhat dismissed Andry and his *Orthopaedia* with the comment that Andry was the first to grasp to the full the role of the muscles as body molders However he does say that "in M Andry we meet the veritable founder of many of our modern orthopaedic practices " Keith directed our attention to the tendency of Andry and

others of his time to attempt artificial "improvements" upon the human figure, as was being done with so many plants trees and flowers. Thus he credited Andry and his generation with many of the devices for shaping the features, the waist and much of the body dyeing the nails and altering the eyebrows the ears and the nose the stock in trade of the "cosmetologists ever since

Andry was most observant, Keith said, of the defects in posture and gait which lead to disability and deformity although lacking information about anatomy and physiology he was most intelligent in his conclusions about measures required for correction Keith did not mention it, but there are similarities between these observations and conclusions by Andry and those of the celebrated Sir Arbuthnot Lane whose application of surgery to the position and the movement of human parts probably has not been excelled.



Fig 1 The "Great Seal" of the American Orthopaedic Association, adopted in 1887



Fig 2 A Emblem on scroll presented by Queen Elizabeth II in London, June 1953



Fig. 2 B The "splint" from the first edition of Andry's book Paris, 1741



L'ORTHOPÉDIE
OU
L'ART
DE PREVENIR ET DE CORRIGER
DANS LES ENFANS,
LES DIFFORMITÉS DU CORPS
TOUT PAR DES MOYENS A LA PORTÉE des Peres & des Meres, & de toutes les Personnes qui ont des Enfans à élever.

PAR M. ANDRY, CONSEILLER DU ROY, Lecteur & Professeur au College Royal, Docteur Regent & ancien Doyen de la Faculté de Medecine de Paris, &c.

Avec Figures.

TOME PREMIER.

PARIS RUE SAINT JACQUES.

Chez { La Veuve Alix, au-dessus de la rue des Noyers, au Griffon. Lambert & Durand à la Sagesse, & à Saint Landry

M. DCC. XLI.

AVEC APPROBATIONS ET PRIVILEGE DU ROY.

FIG 3 The frontispiece and the title page from Andry's first edition, Paris, 1741

Keith joined the critics of "rest" to the extent that he quoted Andry's argument for exercise as follows

> Asclepiades and Erasistratus have boldly condemned all forms of exercise as not only of no advantage but even prejudicial to health, and recommended rest as the chief preserver of it but they were very much mistaken in this point. Rest deserves its own share of praise it is a restorer necessary in the course of a great many diseases. Thus we see that the founder of orthopaedics recognized that rest, as well as action, had its own particular therapeutical merit, but of the two action was that to which he attached the higher value [11]

In Garrison's excellent *History of Medicine* there are two references to "André," the first undoubtedly to Andry for having introduced the word "orthopaedic" the second is for having been the first to describe infra-orbital neuralgia (1756) [10] This latter reference by Garrison to "André" is obviously to Nicolas André (spelled correctly in this instance) and his work on *maladies de l'urètre* (1756) Garrison erred again, I think, in crediting Venel with the establishment of the orthopaedic specialty because he founded the first institution for the treatment of deformities (1780)





FIG 4 Illustrations from the first edition of Andry to demonstrate the use of the "bar" for "spinal curvature" exercises and manipulations for torticollis

Andry's earlier work on animal parasites *De la génération des vers dans le corps de l'homme* (1700) showed extensive observation and much literary labor However it is interesting that some of the descriptions and the illustrations are reminiscent of Ambroise Pare's section on "monsters."[1 16] One gets the impression that Andry accepted both text and illustrations from other authors for some of the "specimens" which he had not seen himself A contemporary Valisnieri thought that Andry claimed to find worms at the bottom of every human disorder and gave Andry the nickname of "Vermicilosus," by which he was called for many years.

Caulfield (1928) in an interesting review of *A Full View of All Diseases of Children* (1742) dismissed Andry and his *Orthopaedia* only giving him credit for the term "orthopédie" However Caulfield was interested in the *De la génération des vers dans le corps de l'homme* of which the English edition appeared in 1701 Caulfield reported that there was little originality in Andry's work on human parasites, with "many of the earlier pediatricians having contributed to this subject but after all it wasn't a bad working basis for that time and forms a very necessary chapter to our little compilation."[7] Caulfield was preoccupied with the apparently unknown author of *A Full View of All the Diseases of Children* which had been attributed to John Martyn (1699 1768) by G F Still[18] It appears to me that Andry situated as he was and with the book's having appeared

the year following his *L orthopédie* very well may have had a hand in it

Andry pursued his studies first at the College des Grassins, with the intention of becoming an ecclesiastic Later he studied medicine at Rheims and Paris and received his medical degree in 1697 at the age of 39 He became a professor in the College of France in 1701 a member of the Editorial Committee of the *Journal des savans* and in 1724 became Dean of the Faculty of Medicine [4 5]

Andry made many contributions to the medical and the scientific literature of the period. Some of these such as the one on animal parasites were not received very well He added to his unpopularity by leading the movement to require all written contributions on medicine surgery and pharmacy to be submitted to the Faculty before publication Also he was among those who persuaded the Cardinal to issue the proclamation that, "desormais les Chirurgiens au moment de faire quelque grande operation se feraient assister d un docteur" This was duly announced in Andry s *Journal* [5]

In the list of Andry s writings are papers on bleeding purging foods the chemistry of certain medicines an "unjust" critique of the work of J L Petit on diseases of bones and, of course his last work *L orthopédie* (1741) He published a second edition of his work on animal parasites in 1702 which was an attempt to reply to the numerous critics of his first one in 1700

Dezeimeris an extremely valuable bibliographic source (not mentioned by Garrison) gave some details about the time between Andry s qualification for the clergy and his beginnings in medicine [9] Andry got his degree as Master in Arts in 1685 and did not abandon the ecclesiastical robes until 1690 After obtaining his medical degree at Rheims he was received by the Faculty in Paris When this body was suppressed by Louis XIV Andry presented himself to the new Faculty and was given a bachelor's degree the same year (1696)



Fig 5 Nicholas Andry

Dezeimeris continued that in spite of doubtful motives and much controversy between Andry and the Medical Faculty Morand, Garengeot, Boudon and the other surgeons were required to submit to medical consultation before their surgical operations Other surgeons not so well known, for whom this practice probably was particularly intended, are not mentioned

Of more importance to us is the statement by Dezeimeris that *L orthopédie* was Andry s most important work. Walter Stuck, in his very good article was one of those who give Andry (spelled "André) a secondary place (as does Garrison) and accord Venel, with his "clinic " greater credit for the origin of orthopaedic surgery as a specialty [10] As I have already indicated, I do not agree with this view Andry s two volumes *L orthopédie* provide a very complete foundation for most of the practices of orthopaedic surgeons especially the French, since 1741

The author of Andry's biography in the earlier *Biographie Univérselle* (1843) doubtlessly upon the authority of some of Andry's critics, wrote that with "un peu de merite et une grande talent d'intrigue" he obtained his various positions of importance and responsibility in the medical affairs of Paris





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However any review of his life from his student days onward suggests that Andry lacked neither ideas nor courage, and his in dustry in numerous directions (making due allowance for the opposition he encoun tered) indicated a keen desire for knowledge and a disposition to be of service to his profession These are fair qualifications for a medical man in any age.

This same biographer asserted that in suggesting that a surgeon always should have a medical consultant for his major operative procedures, Andry simply was trying to dom inate the whole Faculty himself It might appear from this distance in time that An dry having begun a specialty, saw as we often have seen since that supervision of surgical procedures being done by many kinds of surgeons had advantages which were not apparent or at least not acceptable to all of his contemporaries

Andry's contributions to the *Journal des savans* covered a period of 57 years con tinuing to appear until 1759 17 years after his death.

COMMENTS AND OBSERVATIONS

That Andry was entirely aware of the skeletal factor in some deformities is indi cated by one of his earliest statements about curvature of the spine

> Crookedness of the Spine does not always proceed from a fault in the Spine itself, but is sometimes owing to Muscles of the fore part of the Body being too short, whereby the Spine is rendered crooked, just as a bow is made more crooked by tying its Cord tighter

Andry had plenty of precedent for his use of bandages and splints for the prevention and the correction of deformity Such ex cellent works as that of Guido Guidi (Vid ius) published in Paris in 1544 provided him with illustrations from the surgery of Hippocrates Galen and Oribasius [11] Many of these illustrations so well done by Prima ticcio were primarily for w nds and frac tures but all of the fundan ntal ideas for the control of position and c n for immo bilization were inhere t in these earlier pub lications

Andry discussed club foot quite thoroughly in a short paragraph

> That Tendon which goes from the Calf of the leg to the Heel, is sometimes so short, that the Person is obliged to walk upon the fore part of his Foot, without being able to set the Heel to the Ground. Children are some times born with this Defect, and sometimes they come by it afterwards. In either Case it may be cured, provided this Shortness does not proceed from any violent Cause, which has absolutely maimed the Tendon, such as a Burn ing after Birth, for example or any other Accident that is capable of rendering this Shortness incurable.

Under "paratheses" there is an apparent reference to a postparalytic disability of the hand

> (for it is only by this ["nervous"] fluid that they are able to contract) they are not sufficient to resist the Force of their Antagonist muscles, viz. the Flexors In the first place, it must be observed, that the Deformity we talk of is commonly the effect of a billious and convulsive Colick which has preceded it.

There are sections of Andry's book deal ing with "bolt feet, corrective shoes, bow legs, congenital dislocations, including the hip curvature of the spine, active and pas sive motion and defects "

Of supernumerary fingers he said

> the supernumerary one is commonly the Thumb. But whatever Finger it is, you ought to consider whether it is only Flesh, or Flesh and Bones like the rest. If it is only Flesh it may easily be taken off by the means of a Ligature of Silk tied about the Root of it. The Ligature must not be tight at first, but some days after it may be tied a little tighter and so proceed to straighten the Ligature by degrees, 'till at length the Finger withers and drops off of its own accord with out putting the Child to any considerable pain

REFERENCES

1 Andry Nicolas De la génération des vers dans le corps de l'homme 2 vols., ed. 3 Paris, Alix, 1741

2. ——— Orthopaedia, or The Art of Pre venting and Correcting Deformities in Children 2 vols., London Millar 1843

3 ——— L'orthopédie ou, L'art de pré venir et de corriger dans les enfans les

difformites du corps 2 vols Paris, Alix, 1741
4 "Andry Nicolas," biographical extract from Antoine Portal Paris Didot, 1770
5 "Andry Nicolas" Nouvelle Biographie Universelle vol. 1 p 685 Paris, 1843 vol. 2, p 627 1852
6 Bick, E. M Source Book of Orthopaedics, ed 2 Baltimore Williams & Wilkins, 1948
7 Caulfield Ernest A full view of all the diseases incident to children Ann M Hist. 10·409 1928
8 Delpech, J M L orthomorphie 1829
9 Dezeimeris, J E. Ollivier and Raige Delorme Dictionnaire historique de la médecine vol 1 p 138 Paris, Bechet, 1828
10 Garrison, F H An Introduction to the History of Medicine ed 3 Philadelphia, Saunders, 1921
11 Guidi, Guido Commentaries upon the Surgery of Hippocrates, Galen and Oribasius, with the Drawings of Primaticcio Paris, 1544
12. Hunter John Collected Works, ed. by J F Palmer 4 vols. London 1837
13 Keith Sir Arthur Menders of the Maimed, London Oxford 1919 Philadelphia Lippincott, 1951
14 McMurtrie D Am J Care for Cripples 1.27 1914
15 Orr H W History and biography of orthopaedic surgery Am Acad. Orthop Surgeons Instruct. Course Lectures 9 423 1952.
16 Paré Ambroise Thomas Johnson ed. London 1634
17 Pott, Percival Collected Works, 3 vols., London, 1783
18 Still G F Contributions to Medical and Biological Research, Dedicated to Sir William Osler vol 1 p 189 New York Hoeber 1919
19 Stuck, W G Historical backgrounds of orthopedic surgery Ann. M Hist. 7 36 1935

2

Fractures of the Tibial Plateau Treatment by the Assured Fixation Technic

ROGER ANDERSON, M D , F.A C S ,* AND IVAN LOUGHLEN, M.D *

The need for perfection of apposition in treatment of fractures of the tibial plateau is appreciated by most surgeons, but few writers have emphasized the vital necessity of maintaining both chondral and osseous alignment until firm consolidation has occurred Except for the failure of securing primary reduction, failure to supply reliable immobilization of plateau fractures is the prime contributor to the high percentage of deplorable end results

These two factors failure to achieve reduction and failure to provide dependable fixation plus another major error namely failure to employ a practical method of maintaining function, form a dangerous triad that explains most of the poor end-results

Failure to Achieve Reduction. This is explained in part by the stubborn adherence to the old concepts that screw-clamp compression is the vital force for appositional reduction and that strong traction is essential in restoring alignment. Tradition must blind the vision, since it is evident that no amount of compression or traction can replace centrally displaced subarticular fragments Moreover since plateau fractures are like jigsaw puzzles it is clear that reappositions in most cases are achieved by selective replacement rather than by brute compression force

Failure of Immobilization In plateau fractures this is common because these fractures are exceptionally vulnerable to recurrence of malalignment in the preconsolidation period not only because they occur in a weight bearing joint, but also because of the circular and tapered shape of both the thigh and the lower leg The abundance of soft tissue in the thigh loosening of the cast through recession of swelling and shrinkage from muscle atrophy the fracturing of knee ligaments cavitation resulting from a crushing of the cancellous bone and the deforming action of the powerful pelvotibial femorotibial and femorocalcaneal muscles make it impossible for a long leg-cast to hold the reduction. As with spiral or comminuted fractures of the femoral shaft, even a spica cast cannot immobilize plateau fractures

While internal fixation may hold the reduction perfectly under the relaxing effect of the anesthetic when pain returns and the muscles contract, when the cast becomes loose and when the patient becomes more active the articular alignment is lost. This is a tragic condition because malfunction of a valgus-deformed or a varus-deformed knee with unstable ligaments will produce a painful traumatic arthritis frequently to a degree to be classified as a catastrophe

Often, unstable immobilization has followed open operation with placement of bolt and screw as the displacing pull of the strong muscles cannot be resisted by a screw or a bolt that is fastened only a rela

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tively short distance at one end in soft cancellous bone The weakness of such an insertion can be demonstrated by hold ing one end of a pencil in the fingers and noting how little pressure on the other end of the pencil is required to depress or bend the pencil and on the other hand how much weight the pencil will support and how com paratively immobile it is when both ends of the pencil are held by the fingers

Dangerous Practices for Maintaining Function The insistence on following the poorly conceived concept that motion can be restored only through very early movements of the knee joint has made this pain ful manipulative procedure the third major

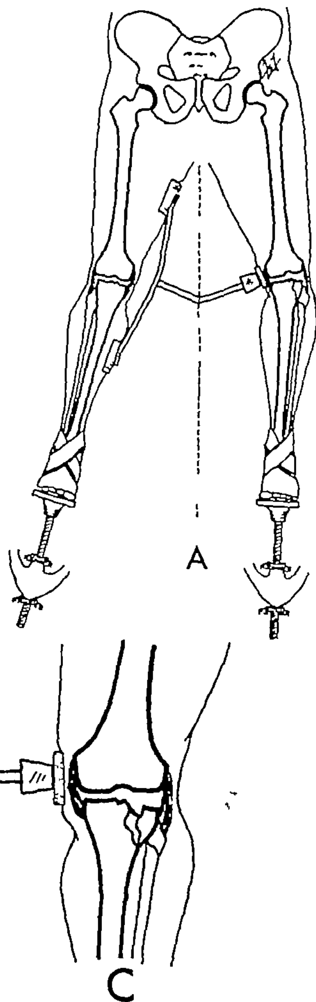


Fig 1 For fractures of the lateral condyle the varus spreader is applied and used as follows (A) With legs in the same plane and the same degree of abduction and rotation, an equal and moderate amount of traction is applied to each leg The assistant carefully brings the foot and the leg on the injured side toward the mid-line until the desired amount of varus is obtained, whereupon the traction frame is locked securely For open operation the spreader is sterilized (B) The usual deformity is displacement in valgus (C) Corrective varus force is exerted after the face of the varus spreader is placed against the distal femur

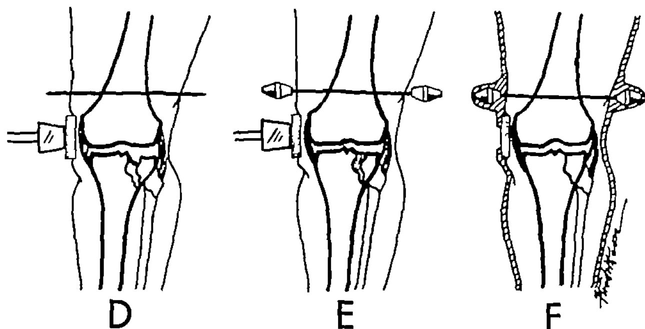
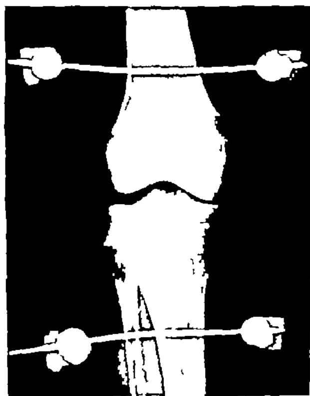


FIG. 1 (*Continued*) (D) One or more femoral anchoring transfixions are inserted (E) The fragment is manipulated and apposed. (F) Firm incorporation of transfixion in the cast from the toes to the groin forms an anchored cast. Tapered sides of the face of the spreader permit easy withdrawal from the cast (not done until cast is set thoroughly) The felt padding prevents window edema.

FIG 2. (*Bottom*) Mrs. M F aged 52 Roentgenogram taken 6-14 54 21 days after *open operation at which time the depressed lateral fragments were elevated and the* crushed bone was replaced by bone bur grafts from the crest of the ilium Note that the incorporated transfixions steadfastly keep the leg immobilized with the knee in varus so that no depressing or displacing force can be exerted upon the articular plate or upon the underlying supporting bone grafts.



cause of poor end results The grievous practice of instituting early joint motion, obtained too often by force displaces the fragments tears the adhesions rends the healing ligaments, increases the swelling, disturbs the alignment and interrupts osteogenesis. Such repeated disruptions miniature re-enactments of the original trauma can only produce complications

For purpose of discussion and as a basis for a definitive system of treatment, the fractures of the proximal end of the tibia have been classified as follows.

CLASSIFICATION OF PLATEAU FRACTURES

1 Fractures of the lateral plateau
   A. Large lateral fragment
   B Comminuted fracture with displacement of the major marginal fragment and the central portion of articular surface depressed distally







FIG. 3 (A *Top left*) Mr M C aged 51 Note the lateral displacement of the marginal fragments. The articular fragments have been outlined to demonstrate more clearly the amount of depression (B *Top right*) Roentgenogram taken during surgery Note the face of the varus spreader on the medial side The joint was opened and a trap door made so that the fragments could be located and elevated The incision had been made over the lateral compartment of the knee joint so that reduction could be checked visually Bone burs from the crest of the ilium were packed firmly into the vacant area and covered by replacing the trap door (C *Bottom*) Roentgenogram taken at 10 weeks. Two months later he had a range of motion from 0 (complete extension) to 120 flexion

2 Fractures of the medial plateau
   A Large medial fragment
   B Comminuted fracture
3 T fractures of the proximal tibia

TREATMENT

In formulating a plan for managing these fractures it becomes obligatory to consider

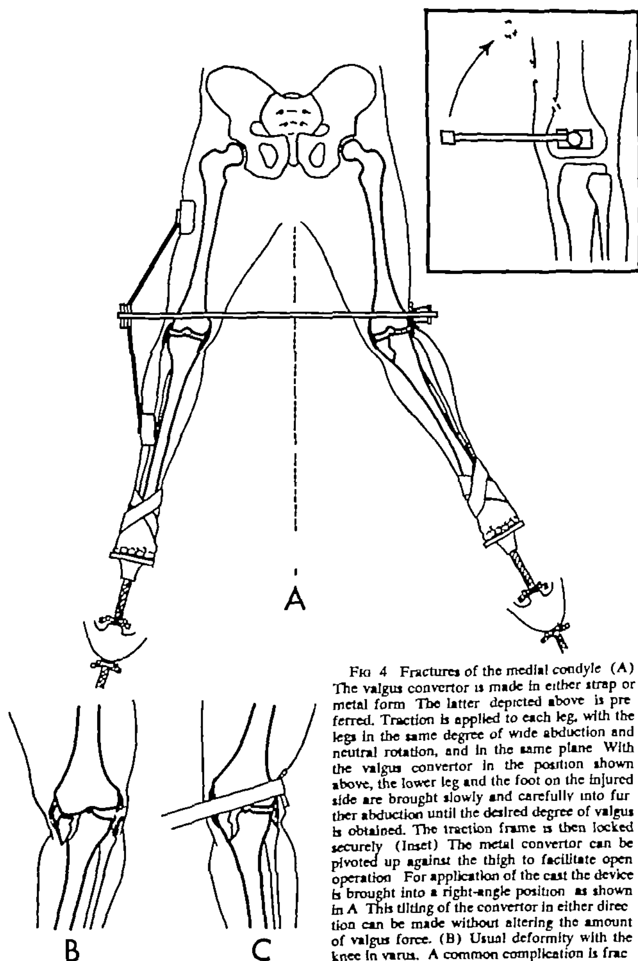
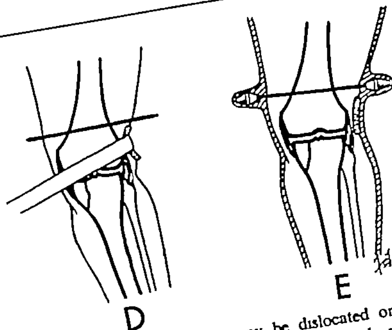


FIG 4 Fractures of the medial condyle (A) The valgus convertor is made in either strap or metal form The latter depicted above is preferred. Traction is applied to each leg, with the legs in the same degree of wide abduction and neutral rotation, and in the same plane With the valgus convertor in the position shown above, the lower leg and the foot on the injured side are brought slowly and carefully into further abduction until the desired degree of valgus is obtained. The traction frame is then locked securely (Inset) The metal convertor can be pivoted up against the thigh to facilitate open operation For application of the cast the device is brought into a right-angle position as shown in A This tilting of the convertor in either direction can be made without altering the amount of valgus force. (B) Usual deformity with the knee in varus. A common complication is frac

turing of the lateral capsule and the external collateral ligament (C) The valgus convertor in strap form is illustrated. (D) Although a single transfixion placed transversely anchors the cast, when swelling recedes sidewise motion can take place therefore the authors prefer to insert 2 transfixions at an angle to each other in the major shaft fragments (E) After the cast which securely incorporates the transfixions or fixation rods, has set thoroughly the strap is withdrawn



the nature of the trauma the character of both hard-tissue and soft tissue damage, the degree of malalignment and the extent of displacement deformities

Fractures of the tibial plateaus may result from a compression force as from a fall or a twisting action and they frequently result from a severe valgus or varus force against the extended knee The knock knee or valgus deformity accompanies fracturing of the lateral plateau, while the bowleg or varus deformity results from a fracturing of the medial condyle

A meniscus may be dislocated or fractured, cruciates torn and the fibula may or may not be fractured, but fortunately the peroneal nerve and the popliteal vessels seldom are injured. Since injuring and fracturing of the soft tissues is a frequent occurrence high priority must be given to these serious injuries in the over all plan of treatment.

In comminuted fractures there is commonly a central and distal displacement of one or more chondro-osseous fragments to a grave extent. At times these fragments are

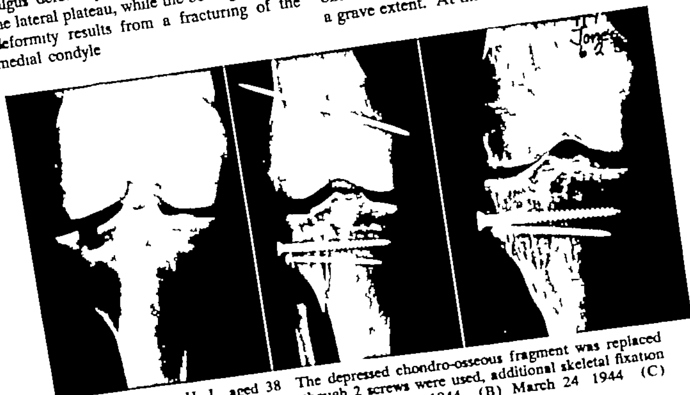
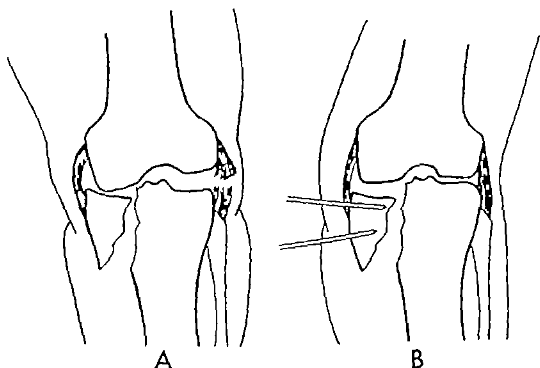


FIG. 5 Mr H J aged 38 The depressed chondro-osseous fragment was replaced under direct visualization Even though 2 screws were used, additional skeletal fixation was, and usually is, advisable (A) January 17 1944 (B) March 24 1944 (C) June 2 1952



FIG 6 Mrs A T., aged 68 As would be expected in the case of a doctor's wife the unexpected occurred The fracture was not only atypical but was complicated by a lateral subluxation Difficulties were encountered in obtaining a final reduction but it was accomplished when the patient and, in fact, the whole hospital started to shake. (This is probably the first time in history that a fracture was reduced by an earth quake a reduction force that is not recommended.) (A) Prereduction roentgenograms taken on April 13 1947 (B) Transfixions were fastened into fixation rods, which were covered with a cast extending from the ankle to the groin (C) Roentgenograms taken 3 years and 7 months later She has extension within a few degrees of complete and flexion beyond a right angle



turned and may lie at right angles or may be turned over completely These displacements invariably occur at the expense of a crushing of underlying supporting cancellous bone

To manage fractures of the tibial plateau and the associated soft tissue injuries a system referred to as the assured fixation technic has been developed This system operates on the following principles

1 Reduction by the employment of a unique form of transverse varus or valgus forces.
2 Replacement of depressed chondro-osseous fragments by pin manipulation or open operation
3 Restoration of crushed cancellous bone with autogenous or banked bone.
4 Assured fixation of reduction through positive immobilization technics
   A. Anchored cast or
   B Transfixions and short cast.
5 Maintenance of function and muscle strength by supplying a safe system whereby the fully clothed patient can be crutch-ambulatory immediately

Routine Technic. The steps in the routine technic for the practical implementation of the above principles are

1 Place the patient on a fracture table and apply traction sufficently to stabilize both legs equally
2 Apply transverse reducing forces.
   A Attach varus spreader and adjust force for fractures of lateral condyle
   B Manipulate tension on the valgus convertor for fractures of medial condyle
3 Reduce and appose fragments by
   A. Manual compression and manipulation
   B Pin manipulation
   C Open operation
4 Immobilize by
   A Inserting 1 or 2 transfixions through the distal femur and forming an anchored cast by firmly incorporating transfixions in a cast extending from the toes to the groin
   B Placing pins through the femur and through the tibia distal to the frac

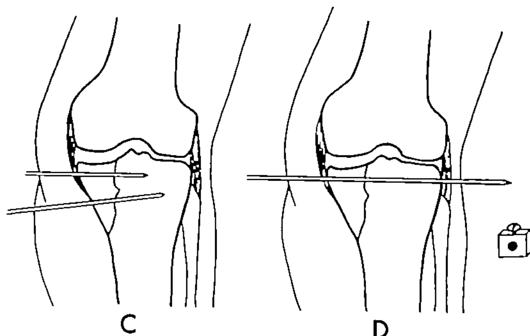
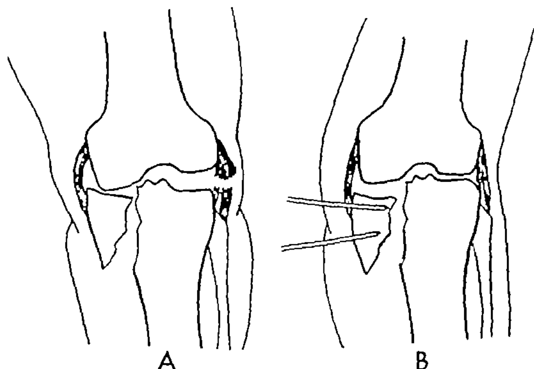


FIG. 7 (A) Direct pin manipulation is often used to replace large fragments. (B) Two or more pins, 4/32 or 5/32 inches in diameter are inserted the depth of the fragment.

FIG 7 (C) Frequently pin manipulation of the fragment can be assisted by external manual compression and manipulation. (D) When roentgenograms reveal satisfactory reduction, the more appropriately placed pin or still another pin, is passed completely through the leg so as to act as a transfixion and later is incorporated in the cast. Care must be taken to avoid undue skin tension during insertion of the pin Cast lug is made with square edges so that the cast lug and the pin will be incorporated solidly in the cast.



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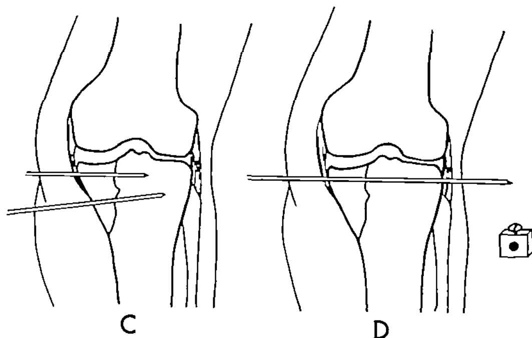


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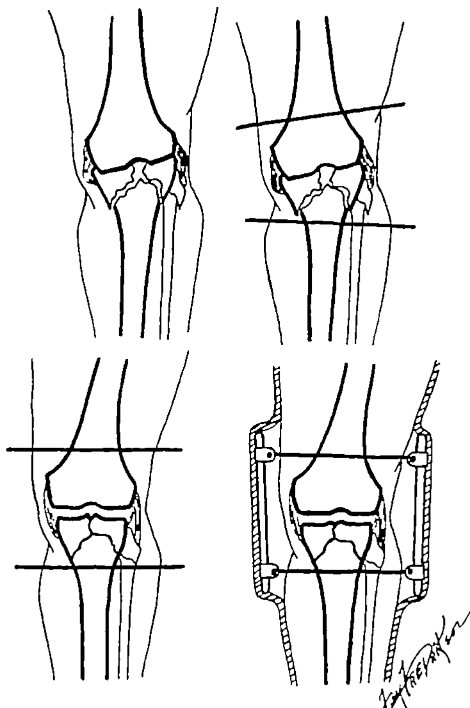


FIG 8 (A *Top left*) For reduction of T fractures extending into the knee joint, or the more extensively comminuted fractures of the upper end of the tibia longitudinal traction may be provided by either the fracture table or the anatomic splint. (B *Top left*) Two transfixions are inserted through the distal femur and two through the tibia just distal to the fracture or above the ankle These transfixions are used not only for immobilization of the fracture but also for manipulation of the fragments (For simplification of the drawing only one transfixion is shown) (C *Bottom left*) Reduction is completed by pin manipulation of the individual fragments or by manual compression and manipulation (D *Bottom right*) Reduction can be held by incorporating the transfixions in a cast or by attaching fixation rods and in turn incorporating them in a cast. In the presence of fractures at multiple levels, transfixions for each individual fracture are inserted, and the fractures are reduced and held separately usually beginning with the fracture at the knee.

ture, and through fragments when indicated and by incorporating pins and fixation rods in a light cast extending from above the ankle to the groin

5 Cut the cast out exposing the patella.

FRACTURES OF THE LATERAL CONDYLE the most difficult of the plateau fractures can be well managed by the routine technic.

The large lateral fragment, if not reducible by pin manipulation, is reduced openly Local fragment fixation is either by through and-through pin or by screw and bolt, but generally cast incorporated transfixions also should be employed

Comminuted fractures with distally depressed chondro-osseous fragments require open reduction including exposing the lateral compartment of the knee joint Fragments are elevated, and if as is usually the case the underlying cancellous bone has been crushed irretrievably bone grafting is necessary Osteogenesis "abhors a vacuum" but unlike nature will not attempt to fill it unless there is a supporting trellis



FIG. 9 (A *Left*) Mrs. A. B Comminuted intercondylar fracture fixed with transfixion attached to fixation rods and incorporated in a cast. (B *Right*) Roentgenogram taken after removal of transfixions.

Bone grafts in the form of burs or a combination of bone struts and burs obtained from the crest of the ilium the opposite tibia a bone bank or a relative should be used to fill in these vacant areas snugly Sufficient new bone which is surprisingly more than the surgeon expects should be used not only to form a support for the chondral fragments but to a sufficient degree to hump up above the normal joint level, because in the ensuing days and weeks a settling occurs A fractured or a dislocated lateral meniscus is not resected, because the authors have found that the meniscus acts as an arthroplastic agent and assists in maintaining the level of articular alignment Later if indicated, which is not often, this traumatized meniscus may be resected but not before strong union has occurred and function has been restored

FRACTURES OF THE MEDIAL CONDYLE This infrequent fracture can be managed by either the routine closed or open technic with the aid of a strap or a metal valgus convertor Pin manipulation is illustrated in Figure 7 At open reduction fragments may be fixed locally by through and through transfixion or by internal fixation with screw or bolt. Even with local fixation, regardless of type frequently it is advisable to use 1 or 2 femoral transfixions Furthermore, the authors prefer to insert 1 or 2 pins immediately below the fracture or through the distal tibia so that no cast need be placed over the foot These transfixions are incorporated firmly in the cast which is applied around the face of the valgus convertor Thus the knee can be held continuously in valgus until the cast dries after which the cast will hold the position dependably until consolidation is complete

COMMINUTED FRACTURES INVOLVING



FIG. 10 (A, *Left*) Mr C G One of the authors was passing through Ely Nevada, and saw the patient in consultation The patient is a miner who sustained extensive injuries, including a fracture of the ankle on the same side as the tibial plateau fracture (B *Right*) The following week Dr T V Ross and Dr W H Frolich obtained this excellent reduction of the plateau fracture By using the transfixion distal to the plateau fracture for countertraction and a transfixion through the os calcis anatomic reduction of the comminuted fracture above the ankle also was obtained A cast was applied from the toes to the groin.

Both Condyles. These are managed with lengthwise traction manual molding and manipulation, pin manipulation and fixation or if indicated with screw bolt or transfixion An intact fibula may need to be osteotomized obliquely for perfection of apposition Immobilization is assured by placing transfixions above and below the frac



Fig 11 Mr H P Extensive compound, comminuted fracture of both legs. Vascular trauma was so severe that the right leg had to be amputated soon after arrival at the hospital (A) A.P view of each leg. The left leg was badly compounded with a resulting loss of bone in the region of the anterior part of the tibia, loss of skin, and detachment of the patellar tendon insertion He was so critically ill that the extensive compound wounds were left open and the leg temporarily immobilized after removing some loose fragments. Ten days later for the tibial reduction one transfixion was inserted through the distal femur and one through the distal tibia. There was extensive fracturing in the region of the upper end of the tibia and the patella had been pulled upward as the tibial tuberosity had been avulsed.

ture These are held with fixation rods covered with a thin cast, or by transfixions firmly incorporated in a cast extending from above the ankle to the groin.

Distraction is an ever imminent danger This may be anticipated partially by reducing the condylar fragments in satisfactory alignment and then joining the pin that has been passed through the articular fragments to the femoral transfixions either with fixation rods or by incorporating the 3 pins in a short cast from the transverse condylar pin to the groin Now the transverse portion of the "T" is reduced independently Traction may need to be increased for reduction and then usually decreased until the surfaces are in intimate contact. Then transfixions immediately below this fracture or above the ankle are joined by fixation rods to the superior rods or by cast to the superior cast. The authors prefer to use fixation rods and finally to cover them with a cast from the ankle to the groin. If preferred, the transfixions may be incorporated firmly into the 2 section cast, which later is joined into one cast extending from the ankle to the groin



FIG 11 (*Continued*) (B *Left*) On the twenty-first day after the accident, an attempt was made to bring the patella down and reattach the tibial tuberosity but the underlying bone was so comminuted and the fragment so thin that there was no means of holding it. A Kirschner wire was placed through the patella to pull it down so that the tibial tuberosity could be replaced into its base Since the patellar ligament was kept relaxed the avulsed tubercle was held in place by closure of the skin. (C *Center and right*) Final result after bone grafting Note the loss of bone anteriorly and the position of the patella. There is complete extension of the knee and flexion beyond a right angle

After-care Success of restoring motion at the knee comes not from early instituting of motion but from postponing all efforts at joint motion until bony consolidation is complete However, resumption of motion and muscle function in all the other joints can be started immediately as the cast extends only from above the ankle to the groin.

Stiffness in the knee can be avoided largely by cutting an adequate hole in the cast over the patella and having the patient, the nurses the family and the doctor noticeably and repeatedly move the patella from side to side and up and down many times every waking hour With this method the patient is fully dressed, crutch-ambulatory and not only is permitted but also encouraged to move the patella contract the quadriceps and move his hips ankles and toes in all directions actively

After the roentgenograms show sufficient bony consolidation, usually a period of from 8 to 12 weeks or more fixation is removed, and active and passive knee exercises are instituted, including quadriceps weight lifting exercises Full weight bearing is not allowed until the roentgenograms show solid bony union.

The best treatment, better than physiotherapy is to have the patient sit on a high table with the lower leg hanging over the edge of the table for periods of 10 minutes on and 10 minutes off at frequent intervals during the day Resting of the foot of the opposite leg on top of the ankle on the injured side increases the leverage Leg baths or whirlpool standing, walking up and down steps and guarded attempts at squatting all expedite early return of motion and strength The patient requires much encouragement and disciplinary action from his doctor but it is surprising how soon the motion returns if these simple chores are carried out enthusiastically and persistently

SUMMARY

Frequency of deplorable end-results in fractures of the tibial plateau are due to (1) failure to effect reduction (2) failure to furnish dependable immobilization and (3) failure to maintain maximum function Of these the failure to supply a reliable means of fixation is the unrecognized cause of a large number of poor end results

A system which precludes these pitfalls has been described The operating principles of this method are

1 Reduction by the employment of a unique form of transverse varus or valgus force.
2. Replacement of depressed chondro-osseous fragments by pin manipulation or open operation
3 Restoration of crushed cancellous bone with autogenous or banked bone
4 Assured fixation of reduction by positive immobilization by
   A. Anchored cast or
   B Transfixions and short cast.
5 Maintaining function and muscle strength by supplying a safe means whereby the fully clothed patient can be immediately crutch-ambulatory

A procedure has been demonstrated whereby all fractures of the tibial plateau, even though complicated by a fracture of the tibial or the femoral shaft, can be managed by a routine technic. This system assures that, except for adjustments at surgeon's direction the reduction will be held so immutably that the strongest and best functioning legs can be obtained in the shortest possible time

3

Fractures of the Patella

PAUL E MCMASTER M.D

The patella which is a sesamoid bone lying in the tendon of the quadriceps femoris is broken not infrequently This occurs by both direct and indirect force

HISTORICAL REVIEW

The pathomechanics of fractures of the patella were recognized long before the advent of modern medicine A textbook of lectures by Boyer published in 1805 describes the mechanics of these fractures He stated

> The transverse fracture is frequently occasioned by a sudden and violent contraction of the extensor muscles of the leg which act on the patella this cause remained a long time unnoticed and the fractures produced by it were ascribed to the fall which was the consequence of the fracture It is at present generally acknowledged to be the immediate cause of the fracture and by that means the cause of the fall

Boyer further stated

> It will be asked perhaps why the tendon of the extensors of the leg and the inferior ligament of the patella are not ruptured rather than the patella itself? To which it may be answered that the extensibility of the tendinous and ligamentous parts renders them less liable to be ruptured than the patella, the hardness of which is more than offset by its brittleness as an osseous substance

However Boyer described avulsion of the quadriceps tendon and of the patellar tendon from the patella as occurring occasionally by indirect force He also reported fractures of the patella resulting from direct force

In 1825 Sir Astley Cooper commenting on the degree of separation of the fracture fragments, stated that this depends on the extent of laceration of the ligaments and that when the capsular and the tendinous aponeuroses are greatly lacerated, extensive separation will be present with an associated early appearance of swelling and ecchymosis Gross in his textbook on diseases of bones and joints published in 1830 discussed fractures of the patella and included an excellent bibliography dating back to 1697

Boyer discussing treatment of these fractures stated

> This chapter might be much extended, by drawing from the profound oblivion in which they are buried the numerous apparatus invented at different and distant times for the treatment of fractures of the patella

Experiments on rabbits and dogs by Sir Astley Cooper in 1825 demonstrated that if the fracture fragments were held together bony union would occur In 1834 Barton initiated fixation of fragments by a wire suture but infection followed and the patient died.

In 1883 Stimson quoted Berger who had listed 91 different methods of treatment, plus 5 or 6 others *for which he could not find references.* Among these were the hooks devised by Malgaigne in which 2 prongs engaged the proximal surface of the upper fragment and 2 prongs engaged the distal surface of the lower fragment. These were connected externally by a bolt, which when tightened with a wrench, approximated and held the fragments together In an effort to bring and hold the fracture surfaces

together, Robson passed a steel pin through the lower quadriceps tendon and the upper patellar tendon and then fastened these externally with sutures There were several modifications of these procedures, which in some instances were successful but painful and not uncommonly led to sepsis

The antiseptic period following Lister's work produced many proposals for surgical repair In 1899 Stimson, commenting on the numerous methods stated that the simplest procedures were preferable and he would reject all in which a permanent suture is placed in the bone itself Still later in 1902 Scudder stated that with conservative treatment the result ordinarily will be satisfactory however, with operation an excellent result can be obtained, but sepsis may occur resulting in a stiff knee, amputation or death.

Describing treatment of these fractures Trethowan in 1921 stated that open operation and suture now are practiced universally and Sir Robert Jones concurred with this opinion

OCCURRENCE AND PATHOLOGY

Fractures of the patella occur most commonly in middle age less commonly in the older age group and rarely in children and adolescents

Indirect force may cause fracture of the patella, and this occurs when the knee is partly flexed and a sudden strong passive strain is placed on the actively contracting extensor mechanism, as in stumbling (Fig. 1) Undoubtedly this occurrence is the cause of not the result of, the fall in a number of cases. However the author does not agree with a number of writers who state that in falls on the knee the force is not taken on the patella but rather on the tibial tubercle Numerous people both children and adults, have been examined and almost invariably in the falling kneeling position the patella not the tibial tubercle is in direct contact with the ground The toes and the forefoot on the ground cause the knee to be flexed more than a right angle thus placing the patella in the most vulnerable position "House maid s knee" illustrates this fact. The tibial tubercle would strike the ground first and take the blow if the feet or the foot hung over a ledge in the fall, in which position the knee is in essentially a right angle position, with the leg parallel with the ground. Thus falls on the knee are a definite cause of fracture of the patella by direct force. Fractures produced by indirect force are usually transverse and may be somewhat comminuted. These may be centrally located (Fig 2) but are more



FIG. 1 Fracture of the patella near the upper pole by indirect force While getting out of his car a 49-year-old male twisted his knee and stumbled but did not fall.



FIG 2 (*Left*) Female aged 35 central fracture repaired with silk. The patient was in a cast for 6 weeks. (*Center*) Same case 7 months later There was apparent bony union and a smooth articular cortex, with normal function (*Right*) Same case. Three years later the patient fell at the beach, with "refracture" At surgery "fibrous union" was found. The lower fragment was removed

often near the lower pole (Fig 3) and occasionally near the upper (Fig. 1) Separation of fragments occurs as a result of quadriceps muscle pull and depends upon the amount of laceration or tearing of the medial and the lateral quadriceps expansion and associated capsular tissue. These tears, which often are extensive at times may extend nearly out to the region of the lateral ligaments, as found by Key and Conwell. The proximal fragment is drawn upward by the contracting quadriceps muscle in cases with extensive lateral tears while the distal fragment, which is held to the tibia by the patellar tendon, does not retract, although it may rotate forward as much as 90° (Fig. 4) In this group with lateral tears, separation also is caused or increased by acute flexion.

Fractures due to direct force occur with the patella being crushed against the femoral condyles, as in dashboard injuries (Fig. 5) These are incomplete (infractions) stellate or considerably comminuted Infractions being incomplete present no serious problem and do not extend to the articular surface. Stellate fractures are complete, and multiple fracture lines are seen, but usually there is little if any displacement. Comminuted fractures often are extensive and present considerable irregularity and disorganization of the articular surface There is usually not much separation of these fractures in the vertical plane as there is little if any tearing of the lateral and the medial expansions The explanation for this is that the direct force to the patella is applied suddenly with little or no associated active contraction of the quadriceps However cases are seen with an apparent combination of both indirect and direct force with not only comminution but also considerable displacement (Fig. 6) The overlying skin and soft tissue may reveal contusions abrasions or a complete compound wound. Fractures by direct violence often cause bruising and tearing of the articular cartilage of the lateral femoral ridge

Occasionally by indirect force avulsion of either the quadriceps tendon or the patellar tendon from the respective patellar poles may occur as described by Boyer

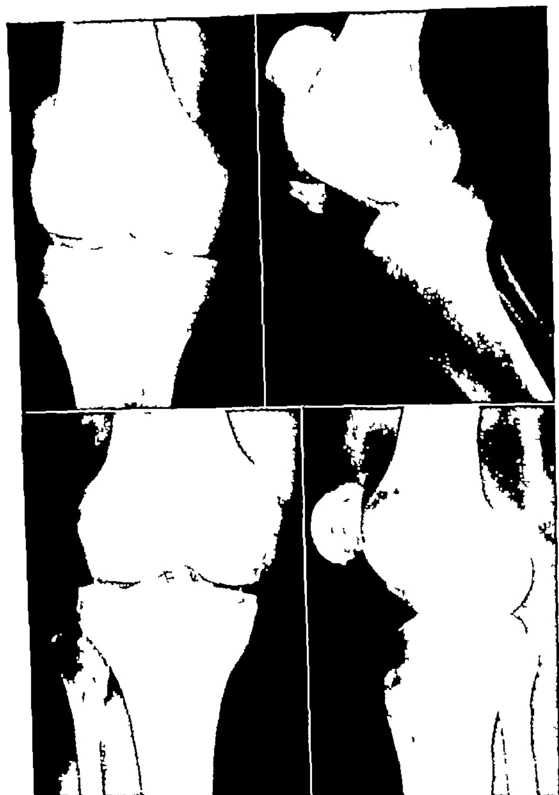


FIG 3 (*Top*) Fracture of the lower pole with separation. Details of the car accident were not clear Probably there was a combination of both direct and indirect force (*Bottom*) Same case 3 years later Primary excision of the lower pole with suture of the patellar tendon to the proximal major fragment with chromic catgut was done with a good result.



FIG 2 (*Left*) Female, aged 35 central fracture repaired with silk. The patient was in a cast for 6 weeks. (*Center*) Same case 7 months later There was apparent bony union and a smooth articular cortex, with normal function. (*Right*) Same case Three years later the patient fell at the beach, with "refracture" At surgery "fibrous union" was found. The lower fragment was removed

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These may or may not be associated with a small flake of avulsed bone Partial avulsions also may occur and one such case was operated on by the author this past year There was a tear of the medial two thirds of the quadriceps tendon at its insertion into the patella.

Almost all complete fractures of the patella communicate with the knee joint and hemorrhage occurs into it Usually there is also extensive extravasation of blood into the surrounding tissues with early appearance of swelling and ecchymosis The swelling may be pronounced, and bullae may form

In old untreated fractures with an initial considerable separation contracture of the quadriceps muscle develops with resulting increased and pronounced hiatus The intervening blood clot "organizes" and a fibrous band connects the separated fragments Occasionally such untreated cases are seen and although the patient can bear weight, the lengthened quadriceps apparatus is weak, and stability of the knee is lacking

DIAGNOSIS

Fractures of the patella are diagnosed by the history of injury the physical examination and roentgenographic study The history reveals a sudden onset of pain, although this may be minimal in association with either a fall or a near fall or a direct blow to the patella Usually the subsequent pain is not pronounced. The examination may reveal a visible and palpable defect between fracture fragments Swelling from hemorrhage develops rapidly and is usually quite symmetrical over the anterior knee joint area Inability to extend the knee indicates that in addition to the fracture there is also a tear of the medial and the lateral quadriceps expansion Ability to extend the knee actively does not rule out a fracture of the patella Crepitus may be present if the fracture fragments are close together but not present if the fragments are widely separated unless they can be brought together manually

The overlying skin may present contu



FIG 4 Anterior rotation of the lower fragment approximately 90 Suture of the fragments gave a good result

sions or abrasions if there was a direct injury In addition if the examination is delayed until the second or third day ecchymosis is present, and bullae may have formed. Compound fractures are usually self-evident with laceration of the skin and the soft parts down to the patellar fragments and exposure of the knee joint

Complete avulsion of the quadriceps tendon will reveal no displacement of the patella, a palpable sulcus and tenderness at the upper patellar pole and inability to extend the knee actively Complete avulsion of the patellar tendon will reveal upward displacement of the patella a palpable sulcus and tenderness at the lower patellar pole and inability to extend the knee actively In neither of these instances will there be a palpable separate bony fragment, and unless taken for soft tissue detail the



FIG. 5 (*Top*) Lateral view of bilateral patellar fractures from a dashboard injury A total patellectomy was performed on the right knee and a partial on the left, with good results. (*Bottom*) Anteroposterior views of the same case

roentgenograms will not show the nature of the injury unless a very small flake of bone has been avulsed (Fig 7) Partial tendon avulsions will show some swelling localized tenderness and weakness in active extension Resistance to the last will be painful.

In those fractures with minimal or no separation, only moderate swelling and tender



Fig 6 Severe comminution displacement and dislocation of the lower fragments Extensive tearing of the aponeuroses was found. Total excision was done with a good result



Fig. 7 (*Left and center*) Avulsion fracture of the tip of the lower pole This fragment was not palpable The articular surface was not involved in the fracture (*Right*) Same case It was treated by excision of the small bony fragment and suture of the patellar tendon to the patella with wire, with a good result

ness are present, and there is no palpable defect and no crepitus Active knee extension is usually possible It is in these that roentgenograms are necessary for diagnosis As a rule postero-anterior and lateral views are sufficient, but in some such as infraction (Fig 8) or vertical fracture (Fig 9) a tangential view (inferosuperior) of the patella is necessary and may be the only view which shows the lesion. This view is taken with the knee acutely flexed and the roentgen rays directed at the patella from below upward. It may be taken with the patient prone and the knee flexed or with him sitting and the knee flexed, as illustrated by Key and Conwell

At times a mistaken diagnosis of fracture is made when a bipartite or a tripartite patella is present. This condition is residual from a developmental variation in which the patella develops from two or more centers of ossification that fail to fuse The most common form (bipartite) shows a bony mass located in the upper outer quadrant of the patella and separated from the main patellar mass by opposing smooth bony surfaces. The 3 roentgenographic views posteroanterior lateral and tangential, are useful in the diagnosis. The condition is usually asymptomatic and requires no treatment.



Fig. 8 Incomplete fracture (infraction) shown on tangential view (inferosuperior) but not visible on routine anteroposterior and lateral views.

However it has caused confusion at times, especially if there has been a history of injury to the knee area One such case came to the author s attention recently The man was involved in a public liability accident, bruising one knee A roentgenogram was taken and diagnosed as showing a fracture A cast was worn for 6 weeks. A subsequent examination to determine the presence of permanent disability for purposes of insurance settlement revealed no disability and similar roentgenographic findings of a bipartite patella were present in the opposite uninjured knee (Fig. 10)

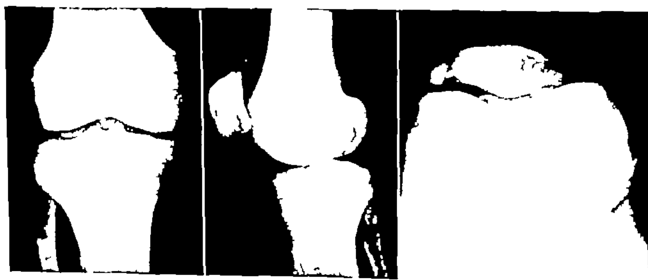


Fig. 9 (*Left and center*) Marginal or vertical fracture faintly visible on postero-anterior view In the lateral view it is somewhat visible (*Right*) Inferosuperior view (tangential) showing the fracture well. After 11 months, there was a painful knee which was treated by excision of the fragment, with a good result.

TREATMENT

Conservative treatment is indicated in those cases where there is no significant separation of fracture fragments with the articular surface showing no deformity and where the patient can extend the knee actively The treatment consists of ice packs and compressive bandages initially to minimize swelling Aspiration of the knee joint is indicated if there is much swelling and



FIG 10 (*Top*) Anteroposterior and lateral views of an "injured" right knee showing a bipartite patella This was diagnosed as a fracture and treated with a cast for 6 weeks. (*Bottom*) The opposite uninjured "normal" (left) knee showing the same finding of a bipartite patella.

fluctuation as the patient is more comfortable, and recovery is more rapid It is helpful also if a cast is to be applied, since it serves as a compressive dressing, thus reducing subsequent swelling. This is done by using a sterile needle and syringe with procaine through a small prepared area of skin near the upper outer margin of the patella Then a cylinder cast is applied, extending from the upper (not middle) thigh to above the ankle As a rule, it is not necessary to incorporate the foot. Then the patient may be up with crutches, and weight bearing is allowed Soon the crutches may be discarded. Gentle quadriceps exercises are started within the first few days and continued regularly The cast is worn for from 3 to 6 weeks, following which the patient gradually recovers flexion and strength by active (not passive) motion.

There is a borderline group of cases. Fracture fragments with a separation of as little as 1/4 in. even if supported, are not apt to heal by bony union but with fibrous union This union may be strong enough for the patient to get along fairly well with care but because of the weakness present, refracture or separation, may occur any time later Hence, in these cases operative repair must be considered.

Operative repair is indicated in those cases with separation of fragments and inability to extend the knee actively This applies for all age groups If some general systemic condition exists such as diabetes, preoperative study and treatment can be carried out to prepare the patient for surgery Hospital facilities with optimum equipment and assistance plus rigid aseptic surgical precautions are necessary

The time for operative treatment varies If the patient is seen early before marked swelling and bullae appear and there are no dirty skin wounds overlying, the knee surgery may be performed immediately Generally the presence of dirty skin abrasions with marked swelling and bullae are contraindications of immediate surgery These should be treated first with bed rest, splinting, hot or cold applications as indicated and antibiotics and surgery should be delayed until the skin is in suitable condition for operation This may require from a few to 10 or 14 days.

Surgery is performed under general or spinal anesthesia and usually a tourniquet is used In the older age group in which circulation may be impaired or questionable it is not advisable to use one. Adequate exposure is necessary and the incision may be median parapatellar or U-shaped The last is preferred by the author It has its base over the patellar tendon with the arms extending far enough upward and outward to allow exposure of the distal portions of the aponeurotic tears Dissection is carried down to the patellar tendon, and gradually by upward reflection the patellar fragments the quadriceps tendon and both the medial and the lateral expansions are well exposed. Wound edges are recovered with towels or if stockinet has been used on the leg, the cut edges of it are fixed to the wound edges by skin clips Some surgeons do not use any special skin cover but practice a "no-touch" technic. Large compressive clamps should not be used on skin edges as the trauma may cause some necrosis of the skin, with impaired wound healing A careful count of skin clips should be made to prevent the later embarrassment of finding a skin clip in the postoperative roentgenograms Fracture fragments are identified, and by retraction the knee joint is exposed Blood clots are removed, and a careful inspection is made of the knee joint, especially to discover and remove any loose fragments of bone The fracture surfaces are bared with a curet. Then copious irrigation of the joint and the wound with saline is done

Then the fracture is inspected, and a decision is made as to excision of bone fragments Advanced degenerative arthritic changes with chondromalacia of articular cartilage and pronounced marginal lippings of the patella and/or the femur are indications for patellectomy or at least for partial patellectomy even though the fracture is



Fig 11 Acute central fracture with advanced chondromalacia of the patella. There were also similar changes in the opposing femoral surface A patellectomy was done, with a good result.

single central and transverse (Fig 11) If excision is not done and the fragments are sutured together bony union may be slow and adhesions and stiffness often develop with limited flexion and late pain from the opposing arthritic changes Avoidance of at least some of these complications can be obtained if excision is done since postoperative motion can be started earlier

With a single transverse fracture in mid-portion and no advanced arthritic changes, the fragments are sutured together while with a larger fragment and one or more smaller fragments at either pole (usually the lower) the latter are removed and the patellar or the quadriceps tendon as the case may be is sutured to the large fragment. Extensive comminution without a single large fragment requires total excision (Fig 12) Approximately one half of the patella in a single fragment is considered adequate to leave This amount refers to the articular cartilage surface, as it should be remembered that the inferior one fourth of the patella is not covered with articular cartilage but is partly for attachment of ligamentum patellae, and the remaining portion is covered by fat pad. Hence a transverse fracture through the mid-point of the patella may leave a relatively small amount of articular cartilage on the distal fragment

Fracture surfaces are freshened with a curet and infolding tags of the overlying

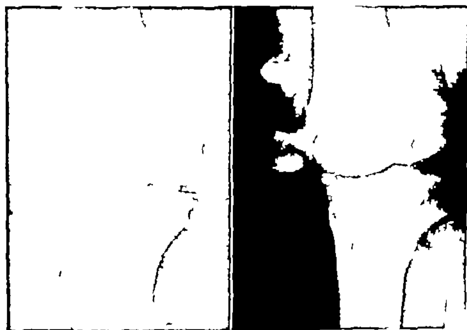


Fig. 12 Marked comminution with displacement. Total excision gave a good result.



FIG. 13 (*Top*) Irregularity of the articular cortex. Suture of the fragments was done with wire and the surgeon felt that he had accomplished a good reduction. (*Bottom*) Same case 2 months later showing separation at the fracture site The wire sutures were too superficial and not fixed firmly enough.



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quadriceps expansions which often partly cover fracture surfaces are reflected or excised A careful, sharp dissection of this expansion from the bony fragments to be removed is necessary as this tissue is used later in the repair

Then mattress sutures of chromic catgut or silk (the author prefers chromic) are placed in the medial and the lateral tears and are left loose without tying. These mattress sutures of chromic are placed through the edges of the medial and the lateral aponeurotic tears and an attempt is made barely to catch the synovial membrane which lies immediately adjacent to the aponeuroses without completely perforating it. However there is no concern if the suture penetrates and lies within the synovial cavity The author prefers to place these first before fixing the patellar fragments as the extent of tearing is seen more easily and their application is easier Then drill holes are made through the fragments in an oblique direction in the sagittal plane Care must be exercised in placing the drill holes so that they exit deep near the articular cartilage but not through it If the drill holes are too superficial tightening of the sutures may create a tilting of the fragments with a resulting hiatus between fragments on the articular surface (Fig 13) Then mattress sutures of stainless steel wire are placed through the drill holes and tied. Two or three are used. Heavy chromic catgut may be used instead of wire but it may fray and break if tied around sharp edges of the bony canal Thus care should be exercised to round off the drill hole edges to prevent this complication if chromic gut is used. Then the loosely placed mattress sutures in the medial and the lateral tears are snugged up and tied A running suture of plain catgut is used to suture the layer of quadriceps expansion which overlies the patella. Subcutaneous tissue is closed with plain catgut, and silk is used for the skin closure Numer



FIG. 14 A fractured patella in a male aged 55 Total excision was done for chondromalacia. There was no postoperative splinting. Dehiscence of the quadriceps suture line occurred 14 days postoperatively It was resutured, with poor results—limited extension and flexion

ous methods have been described and used for fixing the patellar fragments All have been successful These include fixing the fragments with fascia lata (this requires an extra incision) and a circumferential suture about the patella, using wire silk or chromic catgut. However, the use of mattress sutures of wire as previously described for fixing patellar fragments has given good results in the author's experience it is easy and not time-consuming

A similar repair is made when a partial excision has been performed and the patellar or the quadriceps tendon is sutured to a remaining fragment. Drill holes are made in the single fragment as previously described, and mattress sutures of wire or chromic catgut are used to snug the tendon to the remaining fragment.

Repair after total patellar excision is accomplished by placing the sutures of chromic gut in the medial and the lateral tears as previously described. Then the quadriceps and the patellar tendons are approximated and sutured by bringing the quadriceps and the patellar tendon ends as close together as possible but without too much tension The amount of gap if any between the ends will depend on how much time has elapsed after injury Then the upper and the lower flaps (removed from patellar fragments) are overlapped (imbricated) taking up any slack that may be present. Mattress sutures of chromic catgut are applied and are tied along with the previously applied sutures in the lateral tears

Then a cylinder cast in all cases is applied, extending from the upper thigh (not the middle) to above the ankle with the knee extended. A posterior splint may be used Gentle quadriceps exercises are started early and after a few days the patient is allowed up with crutches and protected weight bearing is permitted The crutches may be discarded fairly early if a firm suture has been obtained. Immobilization is continued for from 3 to 6 weeks and then active (not passive) knee motion is started Some writers including Watson Jones state



Fig 15 An old knee injury untreated. There was complaint of some weakness. An apparently old, unrecognized avulsion fracture of the lower patellar pole was present. Complete active extension lacked 10

that immobilization after repair of total excision is not necessary However this author has seen 1 such case which 2 weeks after surgery had a complete dehiscence of the repair requiring resuture the end result was unsatisfactory due to considerable limitation of extension and flexion (Fig. 14)

Fortunately old ununited fractures with separation are not common. These cases with separation usually have a fibrous band connecting the fragments with resulting inability to extend the knee completely There is weakness and the patient may stumble Some learn to live with this disability and may or may not wear a support such as a knee cage or a brace One patient was seen a few years ago who had an old separation of about 1½ in. but he was able to get along quite well with the use of an elastic bandage He was not interested in any surgical repair Thus, indications for surgical

repair depend on whether or not the patient wishes to be able to discard his caution and/or support (Fig 15) He should be informed that surgical correction can be performed, resulting in improved stability but recovery of flexion may be slow and incomplete Repair is accomplished by stretching distally the proximal quadriceps tendon as far as possible Then scar tissue is excised, as well as one or all fracture fragments then, separated tendon ends (usually there is a hiatus) are connected with an interlacing suture of fascia lata, which is preferred to sutures of gut or wire This procedure is preferable to lengthening operations of the quadriceps tendon

Compound (Open) Fractures. The treatment of compound fractures is a surgical emergency for in addition to the compound fracture the knee joint is opened, thus ex

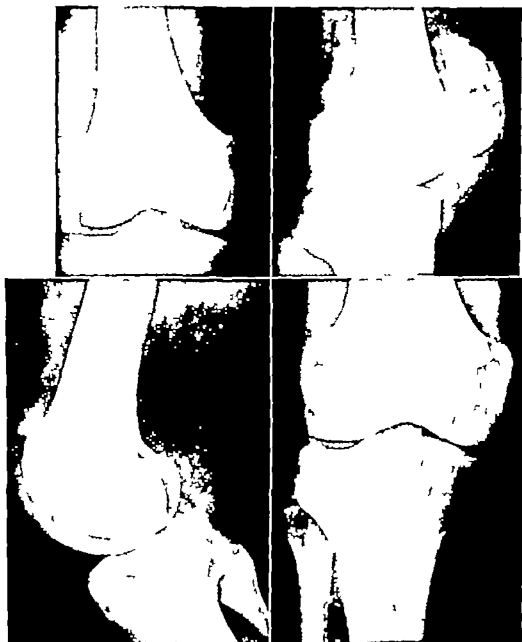


FIG 16 (*Top*) Compound fracture with severe comminution treated by total excision (*Bottom*) Same case 1 year later There was slight "recurrent ossification" extension was limited by 8 and flexion by 30 Some aching was present There was good quadriceps strength.

posing it to the danger of infection. Therefore, it is imperative to hospitalize the patient as soon as possible and to prepare for surgery This should be done as soon as the patient s general condition permits The usual preoperative rules for treating compound fractures apply namely, treating shock and ruling out serious associated visceral injuries, with appropriate attention directed to these if present. Fluid, especially blood, replacement is important.

The surgical procedure includes shaving the entire leg and then scrubbing it thoroughly with Phisoderm for 5 minutes. If Phisoderm is not available, scrubbing with green soap for 10 minutes followed by the use of ether and one of the common antiseptics such as Merthiolate or Mercresin, should be done Then, careful draping follows The wound is inspected and enlarged if necessary in order to expose the knee joint adequately All loose bony fragments and foreign material are removed, followed by excision of the wound edges This excision can be fairly generous, as there is usually ample laxity of skin and subcutaneous tissues to allow a subsequent closure without tension Occasionally however there is initial loss of skin with a resulting defect at the time of injury Following the excision of skin edges and any apparent devitalized tissue the fracture surfaces are cureted. Then the knee joint and the wound are irrigated thoroughly using copious amounts (2 L or more) of saline

Then the soiled and "wet" drapings should be replaced, and the surgeon, the assistants and the nurse should change gowns and gloves and a new set of sterile instruments should be used At this stage in all fresh compound wounds, the operative procedure followed is the same as for a simple fracture (Fig. 16) Prior to the advent of antibiotics often the soft tissues were closed without drainage placing no "buried" sutures in the fracture or the aponeurotic tears. This repair was left to be done as a delayed secondary procedure as cited by Böhler

Following the usual procedure of repair and closure, penicillin (500,000 units) is injected into the knee joint. A cast is applied in the usual manner Postoperatively, antibiotics are administered, and the temperature chart is watched closely The development of a septic temperature demands *uncovering the knee joint for inspection and* local treatment. Should pyarthrosis be present, traction is applied to the leg in order to separate articular surfaces and allow drainage of the knee to be done This can be accomplished by aspiration with a large needle, followed by instillations of penicillin Cultures also should be made of the joint and the wound, and antibiotic sensitivity tests performed with subsequent administration of the most effective drug. Early passive motion can be obtained in these cases by placing a sling under the patient s knee connected by a cord to an overhead pulley and pulled through another pulley over the upper part of the bed for the patient to pull on and hence to flex the knee passively

If the temperature is normal the cast is changed with removal of stitches after from 12 to 14 days and treatment is continued as for a simple fracture

An old compound fracture not seen for several days after injury should be treated similarly to a fresh compound fracture with careful adequate débridement of the devitalized tissues. The fracture and the aponeurotic tears should be repaired, using absorbable suture throughout. The subcutaneous tissue and the skin likewise are closed, and the same program is followed as outlined previously

In the event of a skin defect from initial loss it is especially important to close the knee joint by suture of fracture and aponeurotic tears A skin flap may be swung around (however avoiding any tension on its base) to cover the area of skin defect. Relaxing incisions also can be used to obtain a skin closure

Postimmobilization Treatment. The surgeon should personally and actively supervise the therapy after cast or splint re

moval it is his responsibility Active exercises, with baking and massage should be started immediately but caution is necessary as too much force or effort may cause a refracture In general, early passive flexion is to be condemned. This may be helpful later if flexion is not occurring and the union is considered to be firm Quadriceps exercises, plus gentle and increasing resistance by the therapist, are valuable The patient also can do some weight lifting by sitting on the edge of a table and placing at first a small weight of 2 or 3 pounds on the foot and alternately flexing and extending the knee The amount of weight and the number of times per day can be increased gradually At first the patient should be instructed to walk with a stiff knee and to go up and down stairs one at a time in order to strengthen the quadriceps and the area of union Gradually he will notice increasing flexion and as he does he can begin to walk and to take stairs more normally So long as increasing flexion is occurring and

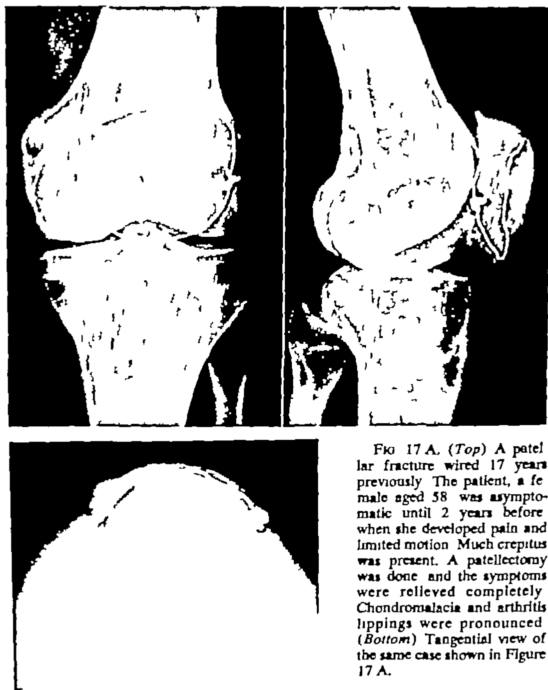


FIG 17 A. (*Top*) A patellar fracture wired 17 years previously The patient, a female aged 58 was asymptomatic until 2 years before when she developed pain and limited motion Much crepitus was present. A patellectomy was done and the symptoms were relieved completely Chondromalacia and arthritis lippings were pronounced (*Bottom*) Tangential view of the same case shown in Figure 17 A.





FIG. 18 (*Top left*) Comminuted fracture treated by partial excision and wire suture of the patellar tendon to the proximal fragment. (*Top right*) Same case 6 weeks later (*Bottom*) Same case 9 months later showing incidental ossification in the patellar tendon The result was good.

despite the time period, which may be from 6 to 12 months there is no need for alarm or the institution of any strenuous manipulative effort. The intra-articular injection of hydrocortisone for aching and stiffness may be useful (the author has had no experience in this type of case) later when union is considered to be firm (at from 2 to 3 months)

Recovery of normal or nearly normal knee motion and strength usually occurs within from 3 to 6 months. In the cases with more extensive injury especially in the older age group recovery may not occur for a year These cases may end with good extension, but normal flexion may be somewhat limited. However as a general rule such limitation is not too disabling

COMPLICATIONS AND PROGNOSIS

Uniformly good results can be expected in treating fractures of the patella if all the various details are observed. Surgery *must* be done at the optimum time and strict aseptic surgical technic must be used. Quadriceps exercises started soon after surgery will help maintain muscle tone and prevent

adhesions and stiffness Some residual limitation in flexion is more apt to result than limited complete extension.

However complications, both early and late do occur, some of which result from inadequate attention to the various details of treatment, while others seemingly develop despite careful attention to details One complication which may occur early is separation or dehiscence of the fracture repair This occurs from either inadequate internal fixation or in some cases at least, no postoperative splinting of the knee. As has been pointed out, late refracture may occur through an area of fibrous union which may have appeared as a bony union Such a case is shown in Figure 2 which occurred 3 years after presumed bony union.

At times stiffness with limited knee flexion is bothersome for several months However a well-supervised program of treatment and exercises as a rule will overcome this the author has followed cases which have not regained full flexion for 1½ years (Fig 3) One patient had, after a year barely little more than right-angle flexion. Improvement continued up to 1½ years at which time she lacked no more than 5° of complete flexion and had complete extension and no complaint

The question often arises whether forcible manipulation should not be done to recover flexion. The author feels that such manipulative efforts especially under anesthesia, are dangerous, with a good likelihood of refracture or avulsion occurring Flexion of 90° without pain and with full extension is not too disabling and as a rule should not be molested Those cases with limited painful motion and a fracture healed with much deformity or with marked arthritic changes and considerable disability may be helped with forceful manipulation. However care must be exercised for these patients patellectomy is generally preferable (Fig 17) Intra-articular injections of hydrocortisone have been most helpful recently in painful cases of chondromalacia and chronic arthritis and should be tried before the more radical procedures

Circumferential wire sutures are apt to break, as shown in Figure 17 while multiple mattress sutures of wire in the fracture fragments as a rule have held up well without breaking There is no concern if the wire sutures break, provided that no separation of fracture occurs

Reformation of bone after partial or complete patellectomy may develop but in no case seen has this caused any symptoms It is seen as an incidental finding in postoperative-check x ray films (Fig 18) Osteogenetic elements left behind after the excision are probably responsible but ossification as far distal in the patellar tendon as shown in Figure 18 is hard to explain on this basis alone It may be due partly at least to a combination of trauma and hemorrhage giving rise to metaplasia within the tendon.

For many years infection with sepsis has been a worry for surgeons in the open treatment of simple patellar fractures However today with proper timing of the operation, improved surgical technic and material (e g. nonirritating stainless steel wire) and antibiotics there is minimal likelihood that this serious complication will occur

REFERENCES

Barton Quoted by Stimson

Berger Quoted by Stimson

Böhler L. The Treatment of Fractures, ed. 4 p 376 Baltimore, Wood, 1935

Boyer Diseases of the Bones, Trans. from French by M Farrell, ed. 1 p 129 Philadelphia, James Humphreys, 1805

Cooper Sir Astley A Treatise on Dislocations and on Fractures of the Joints, American ed. 1 p 158 Boston Wells & Lilly 1825

Gross, S D The Anatomy Physiology and Diseases of the Bones and Joints, p 138 Philadelphia, John Grigg, 1830

Key J A., and Conwell H E. The Management of Fractures, Dislocations and Sprains, ed. 5 p 979 St. Louis, Mosby 1951

Malgaigne Quoted in Bryant, T Practice of

Surgery American ed. 2, p 806 Philadelphia Henry C Lea, 1879
Robson Quoted by Stimson
Scudder C. L. The Treatment of Fractures, ed. 3 p 342, Philadelphia, Saunders 1902
Stimson, L. A A Practical Treatise on Fractures and Dislocations, p 349 Philadelphia, Lea, 1899
Stimson L. A A Treatise on Fractures p 546 Philadelphia, Lea, 1883
Trethowan W H Orthopaedic Surgery of Injuries, Ed by Sir Robert Jones, vol 1 p 79 London, Henry Frowde, 1921
Watson Jones, R Fractures and Joint Injuries, ed 3 vol 2, p 727 Baltimore Williams & Wilkins 1946

4

Fractures of the Patella

ARTHUR S GRISWOLD M.D

Fractures of the patella constitute an important group of lesions requiring treatment by the fracture surgeon, whether he is an orthopaedist or a general surgeon interested in fractures Much has been written concerning these fractures during the past 30 or 40 years and the literature abounds with discussions as to the best methods of treatment and arguments as to their respective merits The pendulum has swung from one extreme to the other enthusiasms have waxed and waned and considerable difference of opinion still exists as to what does constitute the best form of therapy at the present time

Actually the whole problem of treatment of a fractured patella is only one aspect of the problem of the repair of a disruption of the extensor apparatus of the knee which consists of the quadriceps muscle and its tendon, the patella itself, the patellar ligament and the tibial tubercle into which it is inserted. In addition to these there are the lateral expansions of the quadriceps The importance of these in maintaining the strength and the stability of the knee has been stressed repeatedly by various authors notably Groves who went so far as to state that repair of these lateral aponeuroses was the most important feature in the operative treatment of displaced fractures of the patella.[1] Thus it becomes apparent that a disruption of the extensor apparatus of the knee may involve any one of its component elements or as occurs in many instances a combination of two or more of these

Fractures of the patella are esser fractures of adult life, although certain have been recognized to occur in chi and adolescents. The bone is comp cartilaginous in infancy and "is not formed until after puberty probably nc fore the age of 18 "[2]

CAUSES

The causes of such fractures are vai

1 Direct violence such as a direct on the front of the knee or a fall str the patella forcibly against some harc ject, may produce a fracture

2. Indirect Violence. An unexp forcible contraction of the quadriceps cle or a sudden flexing of the knee ' this muscle is in strong contraction ma sult in a fracture of the patella As type is due to sudden tension on the q riceps itself it is readily apparent tha rupture may occur at any level in the tensor apparatus If the quadriceps te gives way it frequently pulls off a small tion of the upper pole of the bone If patellar tendon tears it may avulse lower pole of the patella or more rare fragment of the tibial tubercle or the tella may completely fracture transver allowing separation of the fragments. H ever in all these types of injury as the lence exerted is primarily muscular evident that the lateral expansions of quadriceps are necessarily subjected to same strain and also are ruptured t greater or lesser degree in each instance

3 **Direct and Indirect Violence** It not infrequently happens that the patella first is fractured by a sudden muscular exertion so that the patient falls and strikes his knee directly on some hard object often with resulting comminution of the bone greatly complicating the whole picture and occasionally compounding the fracture itself Or in the case of an automobile collision the passenger seated in the front seat may be thrown forward so as to strike his knee against the dashboard, fracturing the patella. His quadriceps is already in violent contraction in an involuntary effort to protect himself at the moment of impact, and this contraction then serves to separate the fracture fragments grossly and to produce marked ruptures of the lateral expansions on either side which could not possibly be produced by direct violence alone.

4 **A Tangential Force.** This force produces a fracture of the articular surface of the patella, which is broken off from its under surface usually incident to a lateral dislocation of the bone

Fractures from Direct Violence

Fractures from direct violence may be of various types

1 **Simple transverse fractures** without appreciable displacement.

2. **Vertical Fractures.** These fractures may closely resemble a bipartite patella, but the history of injury signs of local pain, tenderness and joint effusion together with roentgenograms taken of both knees usually are sufficient for differentiation

3 **Marginal Fractures.** These fractures are sometimes difficult to demonstrate roentgenologically in the usual anteroposterior and lateral projections A tangential or subpatellar view is usually necessary to visualize the fractured fragment clearly

4 **Comminuted Stellate Fractures.** The violence to produce this type is often severe but actual separation of the fragments may be negligible as the lateral expansions are rarely torn to any great degree

Fractures from Indirect Violence

Fractures from indirect violence or combined direct and indirect violence are the most important from the therapeutic standpoint, as fractures of this type often are accompanied by gross displacement of the fragments wide separation of the torn aponeurosis and consequent complete loss of the extensor power of the knee

Fractures from Tangential Force

Attention to the existence of fractures from a tangential force or osteochondral fractures an unusual type of fracture of the patella, has been called by various authors from time to time notably Meekison[3] Milgram[4] Harmon[5] and Coleman[6] All of these are agreed that the fracture is one occurring in the articular surface of the medial facet of the patella, in which a piece of articular cartilage occasionally thick enough to include a sliver of bone is sheared off from the patella as it slides over the external condyle of the femur during a traumatic or recurrent dislocation of the patella Even earlier reports of these fractures had been made first in 1905 by Kroner[7] who reported one case accompanying dislocation in 1923 by Kleinberg,[8] who reported 3 cases from direct violence on the flexed knee and again by Krida[9] in 1924

TREATMENT

The problem of the management of fractured patellae is hardly one in which a generalized or stereotyped approach to the treatment of all such fractures can be made Each type must be considered separately Obviously certain fractures will do well with a minimum of treatment—only a short period of immobilization or even none at all Thus a transverse or vertical crack in the bone, or even a stellate fracture in which there is no appreciable involvement of the lateral expansions will progress to rapid recovery with purely symptomatic treatment, i.e., aspiration of the complicating hemarthrosis and protection of the joint in

an ambulatory splint or cast for a short period. Quadriceps exercises can be carried out while in the cast and further muscle atrophy can be further prevented by immediate walking without additional support. Such immobilization although not entirely essential is desirable from several standpoints. The patient is more comfortable, and some degree of repair of the lacerated periosteum over the fracture (which after all is part of the quadriceps tendon) will develop before any strain induced by flexion of the knee is permitted. Finally, the knee is protected from secondary injury which may separate the fractured fragments grossly as a result of a sudden flexion of the joint. A recent case which came under observation presented exactly such a picture. A supposed "bruise" of the knee was ignored until sudden flexion a few days later while getting out of bed produced marked separation of a previous transverse crack in the patella and complete disability necessitating operative repair. Early diagnosis and protection of the knee no doubt would have prevented this.

Marginal fractures of the patella do best with surgery. Theoretically the fragment should unite with at least a firm fibrous union and no residual symptoms should remain but in 2 personal cases this has not proved to be the case and localized pain and tenderness persisted until the fragment was excised.

The osteochondral or tangential fractures also have little to do with the extensor action of the knee. Here the problem is that of an internal derangement with a loose body in the joint rather than a disruption of the extensor apparatus. *In the adult the detached fragment* may be recognized readily by roentgenogram and removed through a suitable incision. However in an adolescent this may not prove to be so simple. The fragment detached may be completely or almost completely cartilaginous in character and its localization by roentgenogram is sometimes a problem. However fortunately the fragment is usually so large that it remains in the anterior compartment of the knee joint and can be found and removed through the standard median parapatellar exploratory incision. This exposure renders the under surface of the patella readily available for inspection and facilitates the smoothing-off of any frayed edges that remain. Furthermore in closing the incision the medial capsule may be plicated, and thus the tendency to any further recurrence of lateral dislocation is reduced.

The treatment of the above types of fractured patellae is straightforward, and there is little room for argument or difference of opinion as to the procedure of choice. However when one has to consider the treatment of the various types of fractures of the body of the patella with displacement and consequent disturbance of the extensor power of the knee one finds many opinions expressed often at considerable variance from one another. It is the purpose of the author in this paper to review the various procedures advocated and to indicate what appears to be the most satisfactory type of operation for each particular kind of fracture involved.

A review of the literature shows that as far back as 77 years ago open reduction was undertaken for the treatment of these cases. In 1877 Lord Lister operated on a fractured patella and wired the fragments together.[10] Thus the principle of accurate apposition of the bone fragments and fixation until union occurred was established. However it was not until about 1900 that open reduction and wire fixation came to be the method of choice in the treatment of fractures of the patella with wide separation. Complications in these early cases were many. Infections developed, wires cut through the bone and often broke and had to be removed so that gradually the use of wire as a fixation medium fell into disrepute.

The parade of substitutes for wire advocated by many authors since that time is a lengthy one. These range from the use of simple catgut,[11] cotton,[12] kangaroo tendon fascial transplants,[13,14] strips of quadriceps tendon,[15] double pin fixation,[16] even to the

radical H-shaped bone graft of Albee[17] Those who still advocated the use of wire employed various types—silver phosophobronze malleable iron and in recent years stainless steel.[18]

A perusual of the voluminous literature outlining the various technics of internal fixation shows that in many cases the chief aim has been toward securing fixation of the apposed fracture fragments and immobilization of the part until healing was complete when it was anticipated that function would be restored spontaneously Accordingly following the use of absorbable sutures, prolonged immobilization in plaster was carried out with considerable delay in the restoration of function and all too often a limitation of flexion of the joint, atrophy of the quadriceps and consequent weakness of the knee. Even after fixation with wire the use of brittle wire or that of too small a gauge and weak tensile strength necessitated an undue length of postoperative immobilization and resulting delay in restoration of function.

The principle of securing a fixation of the fragments at the time of operation which was strong enough to permit almost immediate function was stressed repeatedly by Dr George W Hawley of Bridgeport, Conn with whom I was associated for many years[19]

Since that time the principle of secure fixation of joint fractures to permit early motion has been extended to almost every major joint in the body Femoral neck fractures are nailed, external condylar fractures of the lower end of the humerus are screwed or pinned back into place and fractures of the malleoli at the ankle often are replaced and held with screws nails or other fixation media. This principle has been extended to shaft fractures and the various technics of intramedullary nailing of the femur the humerus the tibia and practically every other long bone of the body are gaining increasing popularity

In the case of the fractured patella, Dr Hawley[10] emphasized that treatment was concerned not only with reduction of the fracture and internal fixation of the fragments but also with securing the return of function in the knee as rapidly and completely as possible To this end he emphasized that early motion of the knee was the surest way to prevent muscle atrophy maintain the strength and the tone of the quadriceps and restore the normal range of flexion of the joint. In order to permit this early motion he insisted that complete and accurate fixation of the fragments with the use of strong, nonbrittle wire of high tensile strength was essential To meet these requirements one type of wire was found which has been very satisfactory—a high quality of rustproof iron "stove wire" usually about gauge 18 This has proved to be tough malleable and easy to handle and does not break even when twisted tightly Such slight corrosion of the wire which takes place in the course of years may result in some blackening of the wire and the adjacent soft tissue but this causes absolutely no adverse clinical reaction

Operative Technic

The operative technic for wire fixation of the fracture fragments naturally varies with different types of fractures

1 **Simple Transverse Fracture.** In this fracture after removal of all blood clots between the fragments, two drill holes are made vertically through each fragment, care being taken to select exactly opposite points so that apposition between the fragments will be perfect on tightening the wires The drill holes are started on the fracture surfaces near the articular margins and directed slightly forward to penetrate the upper and the lower poles of the patella. This is essential to secure firm fixation of the entire fracture surface and to avoid tilting of the fragments with a resulting posterior gap in the articular surface on tightening the wires. Two wires are inserted through the respective drill holes The fragments are held snugly apposed with sharp pointed retractors applied above and below and pulled tightly together by an assistant. All slack



FIG 1 (*Left*) Simple transverse fracture with gross separation and some irregularity of fracture surfaces. (*Center*) After wiring with 2 wires Lateral view Note the smooth articular surface of the patella (*Right*) Anteroposterior view of the same case.

in the wire is taken up and the wires are tightened by twisting. Before the final twist, the finger is inserted through the torn aponeurosis on either side of the patella and the articular surface is palpated to ensure absolutely accurate apposition. If slight irregularity exists this can be corrected readily by finger pressure as the wires can be made to cut through the cancellous bone a millimeter or so without difficulty Maintaining this perfect apposition, the wires are tightened very snugly so as actually to impact the fracture surfaces together The excess wires are cut off, and the twisted ends are folded down where they can be embedded in the fracture line or buried laterally beneath the quadriceps expansions Then the tears in the lateral aponeuroses are closed meticulously with silk sutures and the periosteum and the subcutaneous tissues are sutured carefully taking pains to bury the wire beneath them where it cannot be palpated externally

Then the leg may be placed in a plaster cast, a simple posterior splint, or even a large compression dressing for a few days Quadriceps exercises are instituted in a day or two and all support is removed in 5 or 6 days Active motion of the knee is encouraged, and in another day or two the patient is encouraged to get up and walk, often without any support except the arm of an attendant. As soon as confidence is established, it is surprising how rapidly all limp disappears and the motion of the knee returns. In a co-operative patient, flexion to a right angle is anticipated in 3 weeks and full recovery of strength and motion follows rapidly

Figure 1 illustrates the repair of a simple transverse fracture the smoothness of the articular surface which was restored can be seen readily

Objections to this form of treatment have been made claiming that the wires tend to cut through or even to break when extra strain is placed upon them This has not been our experience In only one instance did the wire cut through, and this was many years ago in the case of a woman in whom tabes dorsalis was not suspected before operation Her bones were soft deep sensation in the knee was absent, and there was no voluntary of the joint on walking



FIG 2. (*Left*) Transverse fracture through the upper third of the patella. (*Center*) The same case lateral view after fixation with extra heavy wire showing position maintained and wires unbroken after severe, sudden flexion of unsupported knee 4 days after operation (*Right*) The same case anteroposterior view showing embedding of wire ends laterally in fracture line



FIG. 3 (Left) Transverse comminuted fracture in 3 main pieces with rotation of the central fragment. (*Center*) Lateral view after wiring Note the smooth articular surface of the patella (*Right*) Anteroposterior view



FIG. 4 (*Left*) Extensively comminuted fracture of the lower half of the patella. (*Center*) Lateral view after wiring with one wire loop through the upper fragment above and the patellar tendon below (*Right*) Anteroposterior view showing the wire loop and the apposition obtained

as is present in a normal person. On discharge to her home 8 days after operation she immediately resumed stair climbing using no support, with the result that the wire cut completely through the bone, necessitating rewiring and plaster fixation for a few weeks

To prevent possible breaking of the wire in an unusually heavy patient, it is advisable to employ a heavier gauge wire than usual Fortunately such a heavier wire was used some years ago in repairing the fractured patella of an obese young woman who 4 days postoperatively after all support to the knee had been removed accidentally fell out of a wheel chair acutely flexing the operated knee. In spite of this untoward accident, roentgenograms (Figure 2) showed that the wire had neither broken nor cut through the bone and her convalescence was interrupted in no way

2. Comminuted Fractures of the Body of the *Patella with Separation* These lesions present a different problem and one which further varies in each individual case If the major fragments are large transverse wires through the bones with replacement of the smaller pieces between the larger where they are squeezed tightly in place on tightening the wire, is often the procedure of choice. Of course care must be taken to maintain a smooth articular surface That this can be accomplished even in comminuted fractures is seen in Figure 3

In other instances insertion of the wires through the comminuted fragments may be impracticable A single transverse wire may be passed transversely through a larger fragment and then carried through the quadriceps or the patellar tendon at either pole of the patella, as the case may be snugging the fragments together quite satisfactorily

Figure 4 shows such a fracture with extensive comminution of the whole lower half of the patella This was wired with good fixation but with some residual irregularity of the articular surface However clinically this caused little if any crepitation on motion and functionally the patient secured an excellent result. *This case was operated on in 1936 If seen today* excision of the fragments might be performed but I doubt whether recovery would have been more rapid or the functional end-result more nearly complete.



FIG 5 (*Top left*) Fracture-dislocation of the patella Lateral view showing the knee locked at a right angle (*Top right*) Anteroposterior view Note the large upper fragment of the patella caught behind the femoral expansion above its internal condyle and the comminuted lower fragments caught behind the external condyle. (*Bottom, left*) After reduction of the dislocation and single-loop wire fixation of the patellar fragments, passing through the quadriceps tendon above and the patellar tendon below Note the smooth articular surface of the patella secured in spite of extensive comminution and separation of the fragments. (*Bottom right*) Anteroposterior view

In more extensive comminution of the fracture an encircling wire passing through the quadriceps tendon above and the patellar tendon below often will give excellent fixation although not quite so tight and secure as when the wire includes the bone itself

A case in point is shown in Figure 5 which was most unusual from another standpoint. This man aged 60 had sustained a severe injury which smashed his patella into a number of fragments In some way his knee then became acutely flexed and twisted completely rupturing his quadriceps expansions A large upper fragment of the patella became rotated and was caught behind the inner margin of the femur where it expanded to form the medial condyle while the comminuted fragments of the rest of the bone were displaced downward and laterally where they were caught behind the margin of the external femoral condyle locking the knee in flexion. This extraordinary occurrence resulted in a true fracture-dislocation of the patella When first seen the knee was fixed at a right angle and it was impossible to straighten it until reduction of the dislocated patellar fragments was obtained under anesthesia A few days later the fractured fragments were reduced and held with one encircling wire through the tendons above and below and very extensive lateral tears to the aponeuroses were repaired In spite of the extraordinary amount of injury to the extensor mechanism of the knee in this instance the patient made a very rapid and uneventful recovery No similar case of fracture-dislocation as yet has been found to be recorded in the literature

3 Comminuted Fractures Involving Primarily the Upper or the Lower Pole of the Patella. In these fractures various procedures can be carried out. In some instances the major fragment can be drilled transversely and a single wire passed through this fragment and carried through the quadriceps or the patellar tendon depending on the pole involved. When this is tightened, the comminuted fragments are snugged together as previously described However comminution of the fractured poles of the patella is apt to be so marked that often it is impossible to secure a completely smooth articular surface Because of this in recent years we have come to believe that in many cases excision of the comminuted fragments and reattachment of the tendon to the bone are probably the procedures of choice However in our hands with this procedure the return of function and strength to the knee has not been quite so rapid as when secure fixation of the fragments themselves has been achieved. This seems to be particularly true in the case of fractures of the lower pole Here if the fragmented lower pole is excised and the whole thickness of the patellar tendon is attached to the remaining portion of the bone this portion of necessity must be pulled down and anchored distally to its normal location. The patellar tendon cannot stretch appreciably consequently this abnormal position of the patella persists and in our experience tends to retard the return of function To avoid this it might well be advisable to suture only the superficial portion of the tendon to the bone above However in the case of fractures of the upper pole a different situation exists and removal of the comminuted fragments and closure of the gap by attachment of the full thickness of the quadriceps tendon to the remaining portion of the bone does not appreciably alter the normal location of the patella due to the elasticity of the quadriceps above and little difficulty is encountered in regaining function in the knee

REVIEW OF THE LITERATURE

Excision of all or part of a fractured patella as a form of therapy has been practiced for many years. Heineck,[20] as far back as 1909 reviewed a series of 13 excisions of the patella for various disorders among which were 5 for comminuted fractures of the patella As a result of his review he strongly opposed excision on cosmetic and functional grounds and deplored the loss of protection to the knee joint after

removal of the patella During the next 20 years scattered references were made to extirpation of the patella In 1925 Ludloff[21] impressed by the prolonged stiffness and weakness of the knee following operative treatment and prolonged postoperative fixation recommended resection of the patella for better functioning in various knee affections including fractures In 1935 Thomson[22] recommended partial excision In 1936 Blodgett and Fairchild[23] reported their experience with 55 patients with fractures of the patella in 30 of them partial or total excision had been carried out. However Brooke[24] of England was largely responsible for dissemination of the belief that the patella per se was of negligible importance in the re-establishment of extensor power or function in the knee and in 1937 he reported 30 cases of complete excision.

Since that time partial or complete excision of the patella in the treatment of fractures has been practiced widely Dobbie and Ryerson[25] in 1942 reported 21 cases and advised total excision Some surgeons now advise removal only of comminuted fragments others recommend complete excision Some fail to see any disadvantage in complete patellectomy others find definite loss of extensor power and point out the cosmetic disadvantage of this procedure in the case of women Still others stress the lack of protection afforded to the knee joint after its excision Thus in 1942 Thomson[26] reported an analysis of 544 cases of fractures of the patella, of whom a number were treated by total excision and others by removal only of the loose fragments and plastic repair of the tendon. His conclusion was that total excision was inadvisable as "removal opens the exposed condyles to the constant possibility of minor and severe direct bruising injuries that can lead to intraarticular changes and ultimate disability" He pointed out that "even a fragment of a patella forms a tremendous protection to the large exposed condyles of the femur in case of future accidents" and stressed that this protection was needed, as the knee joint was the largest and yet the most exposed and vulnerable joint in the body Cohn[27] in further stressing this point, reported in 1945 the result of his experimental study with rabbits in which he found that complete patellectomy resulted in "definite pathological changes in the articular cartilage interpreted as degenerative arthritis" Haxton,[28] working along the same line from the reports of previous experimentation as well as his own investigations came to the conclusion that the patella was an integral and necessary part of the knee joint. Not only did it act as a protective covering for the anterior portions of the femoral condyles but also it improved the efficiency of the extension of the knee by holding the patellar tendon away from the axis of the joint, thus increasing the extending movement of the quadriceps pull. With this opinion Rowe[29] concurred and in 1952 advised excision only of the smaller fragments, reserving complete excision for those with very extensive comminution The same conclusion was reached by Jensenius,[30] who reported his experience with 7 excisions of the patella finding it advisable to preserve at least one large patellar fragment. Again in 1951 Langvad-Nielsen[31] reported 6 excisions, partial or total, obtaining a good result in 1 and only satisfactory results in the other 5

In opposition to these findings Schmier[32] in 1945 criticized the older methods of treatment of fractures of the patella with separation stating that bony union was not always obtained and that fibrous union left a sense of insecurity on walking up and down stairs. He further estimated that 10 per cent of fractured patellae suffered refracture and pointed out that malunion with irregularity of the articular surfaces resulted Accordingly he recommended partial or complete excision in all cases to avoid these poor results He further stated that in civilian life simple transverse fracture of the patella comprised the majority of cases and suggested that "total patellectomy might even be preferable here when one considers the

possibility of developing non-union, fibrous union or malunion with secondary arthritic changes and refacture" One can merely point out that only a poorly conceived and executed operation for a simple fracture of the patella could result in any of these complications It would seem that his conception of the proper operative repair of these fractures is open to some question as he goes on to say "patients treated by open reduction require plaster immobilization for approximately 4 to 6 weeks and it may be 4 to 6 months before these patients return to strenuous activity and even then refracture may occur" In contrast with this he states that a stable knee with complete function can be obtained in 6 to 8 weeks after excision. However it might be pointed out that as a military surgeon he was dealing with young, healthy male adults, and although the rapid return of function which he describes is most gratifying others carrying out the same procedure do not report *the same rapid recovery Furthermore the* end results from subsequent trauma to knees subjected to total excision have not yet been ascertained.

More recently Todd[11] in 1950 reviewed 46 cases of fractured patellae of which 16 cases were treated by catgut suture and plaster immobilization for 6 weeks and 30 by excision of the patella. In his critical analysis of the end results he found that the range of movement was slightly better after excision but that the strength of the quadriceps and the consequent extensor power of the knee was better after suture It seems likely that with better operative fixation using wire instead of catgut and early motion instead of 6-week plaster fixation his functional results from open reduction would be even more superior to those after patellar excision

In general a review of the literature of the last 10 or 15 years leaves one with the impression that the enthusiasm with which the use of patellectomy as the treatment of choice for all displaced fractures of the patella was received now has begun to wane Critical analysis of the progress and the end results of cases so treated has depicted certain disadvantages not clearly recognized at first and it would appear that the pendulum has begun to swing again in the opposite direction Judging from the expression of opinion of these various authors and from our own personal experience operative treatment of fractures of the patella appears to fall into the following main categories varying according to the particular type of fracture concerned.

1 **Marginal or Osteochondral Fractures.** These require removal of the split off fragments with the occasional necessity of smoothing off the articular surface of the patella or reefing the medial capsule

2 **Comminuted Fractures of the Upper or the Lower Poles of the Patella** These do best with excision of the fragments and suture of the quadriceps or the patellar tendon to the main body of the bone, followed by early motion.

3 **Transverse Fractures.** *With little if* any comminution these should be reduced accurately with meticulous attention to the contour of the articular surfaces followed by complete fixation of the fragments secure enough to permit early function of the joint. In our opinion, this can be secured best by the use of the proper type of wire

4 **Comminuted Fractures.** Those which divide the bone into a number of large fragments with gross displacement also in many instances may be wired in anatomic position with complete restitution of a smooth articular surface

5 **Extensively Comminuted Fractures.** These may be treated in some cases by snugging together the various fragments with a wire loop sometimes passed through a larger fragment at one pole or they may be treated with primary complete excision. The first leaves the possibility of a delayed traumatic arthritis from irregularity of the posterior surface of the patella the second leaves the femoral articular surfaces largely unprotected, with the possibility of the development of degenerative changes from

subsequent trauma. The first complication if serious still can be treated by the insertion of the ingenious patellar prosthesis recently described by Duncan McKeever but for the second, little relief can be afforded at the present time aside from such radical procedures as arthroplasty or arthrodesis

6 Compound Extensively Comminuted Fractures. In these especially if contamination is marked or the risk of infection and chronic osteomyelitis is imminent, primary total excision of the patella would appear to be the best form of treatment.

SUMMARY

The treatment of fractures of the patella during the past 50 years or more has been reviewed The evolution of the operative repair of these fractures has been summarized and the various methods of internal fixation and postoperative care have been analyzed. The particular operative technic found to be most satisfactory in each type of case has been outlined emphasizing thorough repair of the torn lateral expansions, complete and accurate reposition of the fracture fragments meticulous apposition of the articular margins of the fracture to ensure a perfectly smooth articular contour and rigid internal fixation of the fragments with a strong malleable iron wire of a tensile strength sufficient to permit motion of the knee as soon as the immediate postoperative reaction has subsided.

The treatment of fractures of the patella by excision, either partial or complete has been discussed enumerating the advantages and the disadvantages of such treatment and quoting the end results reported by those who have treated substantial series by this technic. The conclusion has been reached that quite frequently partial excision may be indicated in fractures involving the upper or the lower poles of the patella but that total excision should be reserved for those cases in which comminution is excessive compounding is severe or infection of the bone is imminent or already present.

REFERENCES

1 Groves, E. W H A note on the extension apparatus of the knee joint, Brit. J Surg 24 747 1937

2 Speed Kellogg A Textbook of Fractures and Dislocations, pp 736-758 Philadelphia, Lea & Febiger 1928

3 Meckison D M Hitherto undescribed fracture of patella, Brit. J Surg 25 64 1937

4 Milgram, J E. Tangential osteochondral fracture of the patella J Bone & Joint Surg 25.271 1943

5 Harmon, P H *Intraarticular osteochondral fractures as a cause for internal derangement of the knee in adolescents*, J Bone & Joint Surg 27 703 1945

6 Coleman, H M Recurrent osteochondral fractures of the patella, J Bone & Joint Surg. 30B 153 1948

7 Kroner M Ein Fall von Fläckenfraktur und Luxation der Patella, Deutsche med. Wchnschr 31 996 1905

8 Kleinberg, S Vertical fracture of the articular surface of the patella, J.A M.A. 81 1205 1923

9 Krida, Arthur Osteochondral fracture of the knee joint, Surg Gynec. & Obst. 39 791 1924

10 Lister J A new operation for fracture of the patella, Brit. M J 2 850 1877

11 Todd, J The end results of fracture of the patella J Bone & Joint Surg. 32 B 281 1950

12 Loomis, L. Internal fixation of fractures of the patella, with cotton suture material Surgery 15 602 1944

13 Gallie W E and LeMesurier A. B The late repair of fractures of the patella and of rupture of the ligamentum patellae and quadriceps tendon J Bone & Joint Surg. 9·47 1927

14 Leavitt, P H Fascial strips in patella fractures, New England J Med. 203 728 1930

15 Ober F R. Fracture of the patella, new operation, J Bone & Joint Surg. 14 640 1932.

16 Anderson, R. Ambulatory method of treating fractures of the patella, Ann. Surg 101 1082, 1935

17 Albee, F H Bone graft for fracture of the patella, Internat. Clinics 2.224 1928

18 Michele A. A., and Krueger F Patella fractures a method of wiring, Surgery 24 100 1948

19 Hawley G W Fractures of the patella, Surg., Gynec. & Obst. 67 1074 1937
20 Heineck, A. P The modern operative treatment of fractures of the patella Surg Gynec. & Obst. 9 177 1909
21 Ludloff Resection of the patella for better function, Zentralbl. Chir 52 786 1925
22. Thomson, J E. M Comminuted fractures of the patella, J Bone & Joint Surg 17 431 1935
23 Blodgett and Fairchild Fractures of the patella, results of total and partial excisions of the patella for acute fracture, J.A M.A 106:2-121 1936 (2-1-1)
24 Brooke R. The treatment of fractured patella by excision study of morphology and function, Brit. J Surg 24 733 1937
25 Dobbie, R. P., and Ryerson, S The treatment of fractured patella by excision, Am J Surg 55 339 1942.
26 Thomson J E. M Fracture of the patella treated by removal of the loose fragments and plastic repair of the tendon study of 554 cases, Surg Gynec & Obst. 74 860 1942.
27 Cohn, B N E. Total and partial patellectomy experimental study Surg Gynec & Obst. 79.526 1944
28 Haxton, H. A. The function of the patella and the effects of its excision, Surg., Gynec & Obst. 80 389 1945
29 Rowe C. A. Refracture of the patella following partial patellectomy West. J Surg 60·404 1952.
30 Jensenius, Hans On result of excision of fractured patella, Acta chir scandinav 102 275 1951
31 Langvad Nielsen, A Treatment of fracture of patella, Acta chir scandinav 101 143 1951
32 Schmier A A Excision of the fractured patella, Surg., Gynec. & Obst. 81.370 1945

5

A Presumptive Test for Reduction of Carpal Lunate Dislocation*

GARRETT PIPKIN, M.D

The purpose of the author in this chapter is to describe a presumptive clinical test for reduction of lunate and perilunar dislocations of the wrist. Post traumatic anatomy in either of these types of dislocations produces a lunate mass which encroaches upon the flexor carpal tunnel, limiting finger extension even under tubocurare or brachial block anesthesia Adequate reduction immediately restores finger extension to normal. A knowledge of this mechanism facilitates diagnosis closed and open reduction and convalescent care (Fig 1)

INCIDENCE

Carpal lunate dislocation is rarely encountered in civilian life[9] According to the Blue Shield statistics in the Kansas City Mo area covering a typical fiscal year the number of months of exposure to risk was 3 653 411 During this period Blue Shield paid a total of 114 698 claims[6] The incidence of classified wrist injuries other than sprains was as follows

WRIST INJURIES

INJURY	INCIDENCE PER 1 000 MEMBERS PER YEAR
Colles fracture	0 0623
Navicular fracture	0 0050
Dislocations of one bone	0 0031
Dislocations of more than one bone	0 00031

THE PROBLEM

Such an incidence of wrist dislocations of all types is almost an intangible one so far as insurance risk or availability for teaching material is concerned. An orthopaedic resident on an intensive fracture service such as the Kansas City General Hospital may see only one lunate dislocation during his training period. A rotating intern probably will not see any An additional reason for such a paucity is that many such dislocations are self treated for "sprain." As a result these injuries are overlooked until the late stage when conservative treatment is useless and even skillful operative intervention may be unable to prevent crippling[8,9]

Many failures to make a proper diagnosis arise from dependence upon indifferent roentgenograms. Interpretation of the carpal mosaic presents problems for the expert.[10 12] Such difficulties could be avoided by the surgeon's carefully examining the patient, so that his case is presented to the department of roentgenography for confirmation of the diagnosis rather than for a diagnostic survey

POST TRAUMATIC ANATOMY

Early complete perilunar dislocations present a silhouette which has been labeled "a miniature silver fork" deformity (Fig 2)

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* Read at the Annual Meeting of the American Fracture Association, October 11 1954 Houston Texas.

This deformity is not present unless the main body of the carpus[1] is completely dislocated dorsally and it is soon masked by secondary swelling. It may be seen in late cases after swelling has subsided Usually only the wrist is thickened (Fig 2, bottom) Displacement of the lunate allows the third ray to telescope so that its knuckle is depressed[10] (Fig. 3) The knuckle tapping test of Vaughn and Murphy, positive in navicular fractures is painless in lunate dislocations (Fig. 4)[10]

The fingers are curled in slight flexion *and cannot be extended fully due to blocking* of the displaced lunate (Fig. 1) The greatest limitation of motion occurs in the third ray As the profundus tendon has the greatest pressure on it, the greatest limitation of motion occurs in the distal interphalangeal joint of this finger (Fig. 5) Rupture of the flexors has been reported in neglected cases.[11] Varying degrees of median nerve impairment also result.[3,4,9]

DIFFERENTIAL DIAGNOSIS

When the limited finger extension sign is encountered for the first time in a patient whose wrist, hand and forearm have been casted without reducing the lunate dislocation, the limited finger extension may be confused with an early Volkmann s paralysis (Fig 6) Differential diagnosis from Volkmann s paralysis is made by the absence of severe pain, cyanosis or pallor and totally stiff fingers Removal of the cast does not restore or improve finger extension.

Of more importance than any possible second causal condition in differential diagnosis is the development of a complication inherent in the dislocation itself namely *post traumatic spreading neuralgia (causalgia,*[4] compression neuritis of the median nerve)[3] Lunate pressure on the median nerve results in intense pain, paresthesia, anesthesia, paralysis of the muscles of opposition, atrophy of the median area and a hand that is spastic from pain.[4]

McBride s excellent description of the spastic hand complicating lunate dislocations is pertinent. He states

> At first the fingers are flexed slightly more at the terminal than at the middle phalangeal joints [the basis of the finger extension test —author] but often within two or three



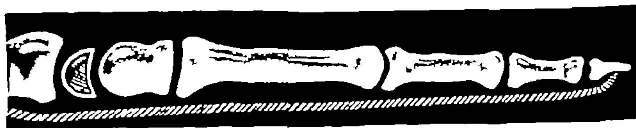


Fig 1 The third finger extension test for carpal lunate dislocation

weeks the pain and stiffness become extremely severe which gives a definite appearance to the hand Fixation of the original spastic attitude gradually takes place. The hand becomes some what mummylike in appearance there is a fixed attitude of slender pronglike fingers and a slightly flexed wrist. To grip the hand gives a cold, stiff feeling as though one had taken hold of a cadaver Codman and Chase, in describing one of their cases say that "the hand looks as though it belongs to another person" The palm is moist, the knuckles are prominent, the skin is glossy and firmly adher ent to the subdermal tissue. The fingers can not be extended by passive force and flexion is limited to a few degrees. Manipulation seems more like the bending of solid rubber fingers than the gliding of joints.

Because of atrophy the fingers seem slender and are separated at their bases, which gives them a fork prong appearance. There is a slight prominence at the base of the palm. The

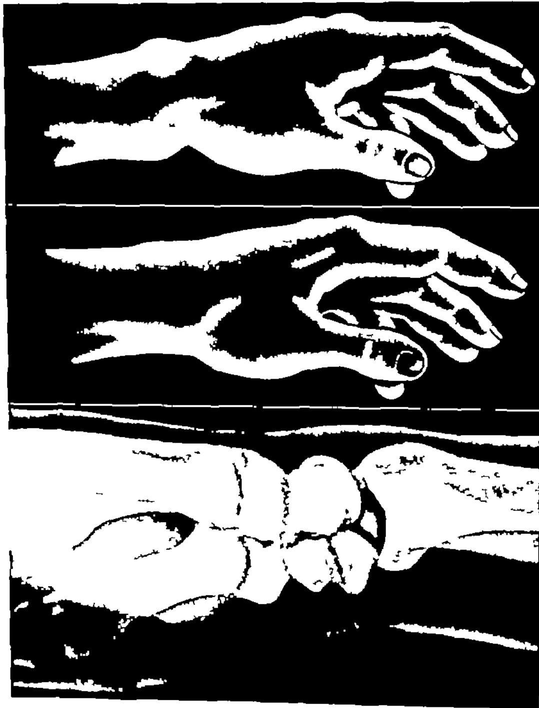


FIG. 2. "Miniature silver fork" deformity is present only in complete dorsal perilunar dislocations. (*Top*) "Miniature silver fork." (*Center*) Normal. (*Bot tom*) Perilunar dislocation with thickened wrist only

thenar eminence is somewhat atrophied, and the thumb is held close to the forefinger Atrophy extends up the forearm, rotation be ing considerably limited

The outstanding subjective symptom from the beginning is persistent pain of a burning pressing nature, unrelieved by splints, or the position of the hand. Other symptoms are general numbness of the fingers and palm, and sometimes there is a tingling sensation in the first and second fingers on movement of the wrist. The feeling in the fingers is compared by the patients to that of a hand covered with a glove.[5]

Development of a causalgic state in lu



Fig 3 Depression of the third metacarpal knuckle seen as a result of lunate dislocations.



Fig. 4 The knuckle percussion test is positive in navicular fracture negative in lunate dislocation.

nate dislocation carries a grave prognosis One of McBride s cases became a narcotic addict and committed suicide 2 years following injury[9] Bunnell states that in complete dislocations such disability is permanent, but if the dorsal radiolunate ligament has not been ruptured so that the displacement is only partial the permanent disability may be slight.[4] *Obviously it is of the utmost importance that a surgeon considering*



Fig 5 The finger extension test for carpal lunate dislocation

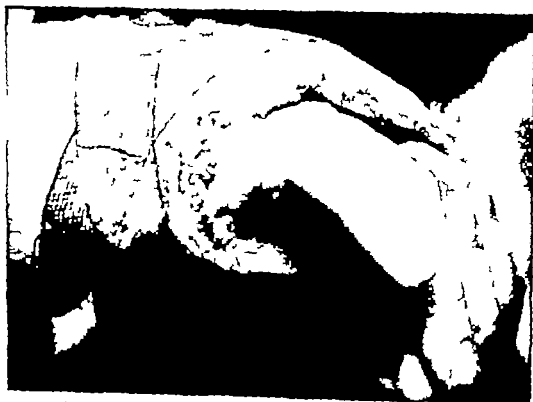


Fig 6 Dislocated lunate or Volkman s paralysis? (See text.)

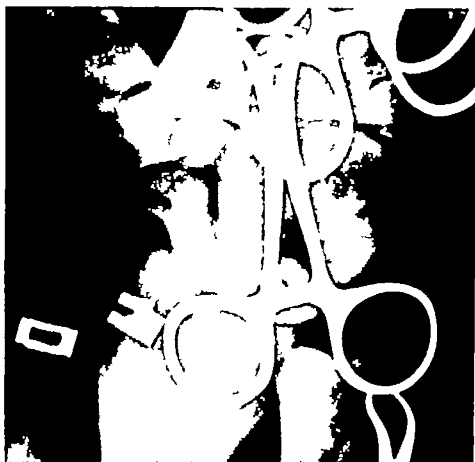


FIG. 7 Is it reduced? The field is obscured by surgical instruments.



FIG. 8 Is it reduced? The field is obscured by the plaster cast and poor lateral positioning

closed or open reduction of a lunate disloca tion determine whether he is dealing with simple mechanical flexor tendon contrac ture or with the spasticity of a causalgic state

While not within the scope of this chapter the author wishes to point out that a discus sion of recognized methods of treatment of causalgic states such as repeated procaine stellate blocks, ganglionic blocking drugs sound or roentgen-ray therapy and sympa thectomy in relation to lunate dislocation causalgia was not encountered in his review of the literature. Any surgeon with experi ence in these various types of therapy for this entity could make a valuable contribu tion to the literature by reporting them

CLINICAL APPLICATION

This characteristic limitation of finger ex tension is pathognomonic of lunate disloca tions as numerous contributions to the medical literature record[7,8,9,11,13] It is a useful tool in the management of this injury From post traumatic anatomy it is self-evident that this sign will persist, even under adequate anesthesia, until the block to the flexor tunnel has been relieved by reduction of the dislocation or extirpation of the lunate (Fig. 1)

After closed or open reduction the restoration of finger extension is immediate and may be considered a presumptive sign of reduction This obviates an unnecessary hazard for those surgeons who still do fluoroscopic reductions. It is an adjunct to open reductions, in which proper operating room roentgenograms may be obscured by instru ments in the surgical field (Fig. 7) After reduction and check roentgenograms, a change of position may occur during the application of a cast even with a skilled team. Under such circumstances it is most comforting to test the finger extension in the final assembly

The finger extension test is also useful during the convalescent cast period The presence of a cast adds to the technical difficulties of making and interpreting roent genograms (Fig 8) A postreduction case with a positive limited finger extension test should have the cast removed for a more nearly accurate evaluation of the reduction.

REFERENCES

1 Babcock, W W Principles and Practice of Surgery p 449 Philadelphia, Lea & Febiger 1944
2 Böhler L. Treatment of Fractures, p 236 Eng trans. by E. W H Groves Baltimore Wood, 1935
3 Bruni A. Compression neuritis of median nerve by luxated semilunar bone, Rassegna Previd. Sociale 24 42, 1937
4 Bunnell, Sterling Surgery of the Hand, ed. 2, p 687 Philadelphia, Lippincott, 1948
5 Codman and Chase Ann. Surg. 51 863 1905 quoted by McBride
6. Collins, Tom Personal communication
7 Howorth, M B Text Book of Orthopedics, p 577 Philadelphia Saunders, 1952
8 MacAusland, W R. Perilunar dislocation of the carpal bones and dislocation of the lunate bone Surg., Gynec. & Obst. 79 256 1944
9 McBride E. D Dislocation of the semi lunar bone neurospastic fixation of the hand, a deformity characteristic of the injury Arch. Surg. 14 584 1927
10 Murphy J B Clinics of John B Murphy 1915 pp 383-421 Philadelphia Saunders 1915
11 Spiegel, H. Spontaneous rupture of the flexor tendons in a patient with old dorsal perilunar luxation of the hand, Monatsschr Unfallh. 52.314-316 1949
12 Stevenson L. D Dislocations of carpal lunate, Brit. M J 1 129 1940.
13 Watson-Jones, R. Fractures and Other Bone and Joint Injuries p 419 Edin burgh, Livingstone 1940

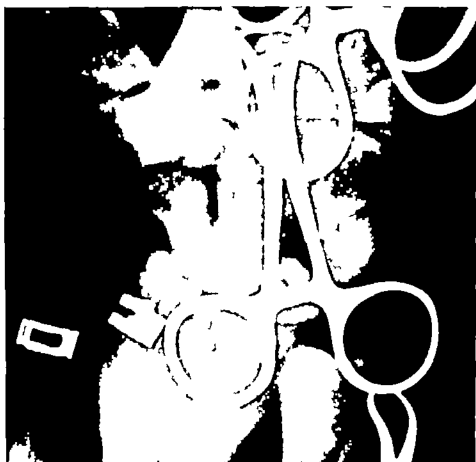


Fig 7 Is it reduced? The field is obscured by surgical instruments.



Fig. 8 Is it reduced? The field is obscured by the plaster cast and poor lateral positioning

closed or open reduction of a lunate dislocation determine whether he is dealing with simple mechanical flexor tendon contracture or with the spasticity of a causalgic state

While not within the scope of this chapter the author wishes to point out that a discussion of recognized methods of treatment of causalgic states such as repeated procaine stellate blocks ganglionic blocking drugs sound or roentgen-ray therapy and sympathectomy in relation to lunate dislocation causalgia was not encountered in his review of the literature. Any surgeon with experience in these various types of therapy for this entity could make a valuable contribution to the literature by reporting them

CLINICAL APPLICATION

This characteristic limitation of finger extension is pathognomonic of lunate dislocations, as numerous contributions to the medical literature record[7 8 9 11 13] It is a useful tool in the management of this injury From post traumatic anatomy it is self-evident that this sign will persist, even under adequate anesthesia, until the block to the flexor tunnel has been relieved by reduction of the dislocation or extirpation of the lunate (Fig. 1)

After closed or open reduction the restoration of finger extension is immediate and may be considered a presumptive sign of reduction This obviates an unnecessary hazard for those surgeons who still do fluoroscopic reductions. It is an adjunct to open reductions in which proper operating room roentgenograms may be obscured by instruments in the surgical field (Fig. 7) After reduction and check roentgenograms a change of position may occur during the application of a cast even with a skilled team. Under such circumstances it is most comforting to test the finger extension in the final assembly

The finger extension test is also useful during the convalescent cast period The presence of a cast adds to the technical difficulties of making and interpreting roentgenograms (Fig 8) A postreduction case with a positive limited finger extension test should have the cast removed for a more nearly accurate evaluation of the reduction

REFERENCES

1 Babcock, W W Principles and Practice of Surgery p 449 Philadelphia Lea & Febiger 1944
2 Böhler L. Treatment of Fractures, p 236 Eng trans. by E. W H. Groves, Baltimore Wood, 1935
3 Bruni, A Compression neuritis of median nerve by luxated semilunar bone, Rassegna Previd. Sociale 24 42, 1937
4 Bunnell, Sterling Surgery of the Hand, ed. 2, p 687 Philadelphia, Lippincott, 1948
5 Codman and Chase Ann. Surg 51 863 1905 quoted by McBride
6 Collins, Tom Personal communication
7 Howorth M B Text Book of Orthopedics p 577 Philadelphia, Saunders, 1952.
8 MacAusland W R. Perilunar dislocation of the carpal bones and dislocation of the lunate bone Surg. Gynec. & Obst. 79-256 1944
9 McBride, E. D Dislocation of the semilunar bone neurospastic fixation of the hand, a deformity characteristic of the injury Arch Surg 14 584 1927
10 Murphy J B Clinics of John B Murphy 1915 pp 383-421 Philadelphia, Saunders, 1915
11 Spiegel, H. Spontaneous rupture of the flexor tendons in a patient with old dorsal perilunar luxation of the hand, Monatsschr Unfallh. 52.314-316 1949
12 Stevenson L. D Dislocations of carpal lunate Brit. M J 1 129 1940
13 Watson-Jones, R. Fractures and Other Bone and Joint Injuries, p 419 Edinburgh, Livingstone 1940

6

Injuries of the Hip

JUSTUS C PICKETT, M D

Injuries of the hip joint have been observed for hundreds of years and were described both as to occurrence and treatment long before roentgenograms were available for confirmation. Dislocation of the hip itself is considered to be a somewhat uncommon injury and is said to occur in only 2 to 5 per cent of all patients with traumatic injuries Previous reports of traumatic injuries of the hip from various parts of this country have been grouped into those occurring as a result of automobile accidents [3] the result of wartime injuries[5,6] and as a result of falls, etc. This series of cases represents those that have been seen for the most part in a mining community It includes all of the usual types of injuries and in addition many persons injured in the coal mines These injuries are frequently very severe in nature and often are associated with other serious injuries.

ETIOLOGY

Injuries to the hip may occur in many ways The typical description of the so-called "dashboard injury" occurs when a passenger riding in the front seat of a car suddenly is thrown forward, striking the knee which is crossed over the other leg against the dashboard. Exactly the same mechanism can occur when a miner is in a bent position and a fall of the roof occurs, striking him across the back, forcing his pelvis forward against the fixed leg. Fixation of the foot often produces more damage to the acetabulum. Falls in which a person strikes his knee or falls from a heigl though he lands on his feet, can the same type of injury In the mi dustry many of the injuries to the h occur when a person is squeezed, e two moving vehicles or by one mo hicle against the side of the mine sition of the limb at the time of the determines to a large extent the typ jury that occurs

ANATOMY

Usually the hip is regarded as a stable joint. The capsule is fairly veloped and is reinforced in the fr the superior portions by the Y-li The weakest portion of the joint is be posteriorly inferiorly but anter feriorly it is also weak The circul the hip itself comes from several The ligamentum teres which exten the base of the acetabulum into th contains a fairly large vessel althoug discussion has occurred in the past c ing the value of this ligament to joint, Chandler has shown that it do tain a significant blood vessel in the adult [2] He was able to demonstrate a tomosis between the vessels of the l and the head of the femur in 109 patients who were studied Circula the head also is maintained through t sels in the capsule chiefly through t terior retinaculum. The nutrient from the upper shaft of the femur only to the base of the neck itself

TYPES OF INJURIES

Dislocation of the hip joint is said to be most frequent through the postero-inferior portion of the capsule and this particular dislocation occurs when the injury or the force is against the flexed adducted thigh. Considerable force is required to dislocate the hip As a result of experiments it has been estimated that it requires several thousand pounds acting at the time of maximum force to produce a dislocation of this joint. If the leg is extended at the time of the application of the force the posterior margin of the acetabulum often is broken and carried upward with the head of the femur itself Dislocations anteriorly occur when the leg is abducted widely and the head of the femur slips into the obturator region if the thigh is in flexion or into the anterior or the pubic region if the leg is extended Central dislocations occur when considerable force is exerted against the hip such as being squeezed between two objects and it will depend upon the amount of force and the length of time in which it acts as to how much protrusion of the head of the femur into the pelvis takes place. Such an injury often is accompanied by hemorrhage in the retroperitoneal region, fractures of the pelvis injuries to the genito-urinary system and frequently by fractures of the other extremities

PATHOLOGY

The pathologic changes that may occur in injuries to the hip in the simplest of dislocations involve tearing of the capsule and the ligament. The tear usually occurs at the attachment of the capsule to the margin of the acetabulum If fracture occurs with the dislocation, the size of the fragment may vary from a small section of the margin of the lip of the acetabulum to the entire posterior wall or at times a portion or all of the head of the femur The soft tissues, comprising not only the capsule but also the muscles in the region of the hip frequently are torn, producing hemorrhage and eventually this may result in calcification or the occurrence of myositis ossificans Injury to the soft tissues with interruption of the blood supply to the head of the femur is undoubtedly the major factor in the later development of avascular necrosis and traumatic arthritis Delay in reduction, with prolonged pressure, adds to the extent of thrombosis. Trauma itself appears to precipitate some alteration in the articular cartilage as well as the bone, as the changes seen following stellate injuries to the acetabulum as well as complete central dislocation are usually severe The addition of surgical trauma when open reduction is necessary adds to the incidence of complications. Injuries to the sciatic nerve may occur both in posterior displacements and in those patients in whom intrapelvic or central dislocation occurs The nerve may be stretched over the head of the femur as it is displaced or the nerve may be contused by direct injury Complete severance of the nerve has not occurred in this series, but severe contusions have been seen

CLASSIFICATION

For purposes of this paper these cases are classified into "acute" and "old" injuries Acute injuries are those that had occurred recently or were under treatment for the original injury The older cases are found in persons who came because of pain, disability or both and were seeking relief from their symptoms or evaluation of their disability

The acute cases are classified into simple dislocations either anterior or posterior dislocations with fracture of the rim of the acetabulum, central dislocations with a partial or complete fracture in the floor of the acetabulum and dislocations associated with fracture of the head of the femur

Simple Dislocations

Acute dislocations of the hip usually can be cared for simply and without surgery Conservative treatment always should be given a fair trial, but undue violence never



FIG 1 The original injury was a posterior dislocation of the head of the femur with a fragment of the head in the acetabulum. *This roentgenogram was taken* after forceful manipulation of the hip showing complete fracture through the neck with one fragment lying posteriorly and another lying within the acetabulum. The patient had other injuries and expired on the day after reduction

should be necessary in reduction of the hip When the head is extruded through the capsule, failure of reduction usually means that soft tissue is looped over the neck or that the rent in the capsule has contracted behind the head of the femur In such patients when gentle manipulation has failed to restore the proper relationship this tissue must be displaced surgically at the earliest possible time in order that reduction may be obtained. It is imperative that treatment in these patients be carried out without delay The usual methods of reduction for dislocation which have been described by Allis Bigelow and Stimson have been employed at various times using the simplest type of maneuver that would accomplish reduction Circumduction as described by Bigelow has been avoided if possible as that may add additional injury if it is carried out forcibly In the first group there have been 6 anterior and 9 posterior dislocations which we have been able to follow In our reductions we have been fortunate for the most part by being able simply to lift the head of the femur into the joint under complete relaxation Forcible attempts often produce very serious complications (Fig 1) Following reduction, at times we have used traction but at present immobilization in a hip spica for 8 weeks followed by gradual activity on crutches is followed by physical therapy muscle training and gradual resumption of weight-bearing in 3 to 4 months There has been no substantial evidence that prolonged non weight bearing in simple dislocations prevents the occurrence of avascular necrosis Banks was of the opinion that changes could be detected much earlier however in those persons who remained on crutches for at least 6 months.[1] These 15 patients in the author's series were reduced within the first few hours after injury the longest time being slightly more than 6 hours The patient who was reduced after 6 hours was transported 60 miles after unsuccessful closed manipulation and open reduction here revealed soft tissues around the neck of the femur including a contused sciatic nerve After only 6 months the hip shows 50 per cent limitation of motion decrease of the joint space and a peroneal nerve paralysis At the present time the remaining patients have shown no evidence of avascular necrosis or arthritis Limitation of motion is not a factor of disability in any of them and other than the complaint of occasional aching after walking there is no pain The period of follow-up varies from 15 months to 15 years.

POSTERIOR DISLOCATION WITH FRACTURE OF THE ACETABULUM

When dislocation of the hip is accompanied by fracture of the posterior rim of the acetabulum, it is necessary not only to reduce the displacement of the head but also to replace the fragment of bone into its normal position. Incomplete reduction of the joint or the fragment often is followed by rapid disintegration of the joint cartilage The slightest irregularity of the articular surface in a weight-bearing joint is undesirable In those patients in whom the fragment was small and reduced satisfactorily traction was maintained for from 6 to 10

weeks followed by a period of non-weight bearing for at least 3 to 4 months.

In this group there were 8 patients Closed reduction was carried out immediately but in those persons in whom the fragment was large or the displacement could not be reduced, open reduction was performed as soon as possible. Internal fixation of a large fragment may be delayed for as long as 10 days Six patients were treated by open reduction In 2 of them a *screw was not used at operation because* the fragment was secured very well without fixation. Subsequently 1 showed slight absorption but the patient has had no further difficulty from his hip joint and after 7 years he is flying jet fighter planes for the U S Army Air Force In the other slight pain has developed, and *early traumatic arthritis* probably is developing

Four of the patients were treated by fixation with screws The operation was conducted through a posterior incision with the patient lying on his face Following exposure of the hip joint, the area was irrigated thoroughly to remove all debris after which the fragment was fitted carefully into place and secured with a screw passing into the ilium (Fig 2) Small fragments that were free were removed from the joint.

One of the 4 patients in this group originally was treated in a hospital at some distance Following unsuccessful closed manipulation he developed a pulmonary embolus and was observed carefully for about a week before being moved to our hospital The posterior dislocation was still present, and operation was carried out the following *day through a posterior incision* The head was lying against the posterior brim of the ilium and the joint was filled with blood clots The articular cartilage was dry and showed a yellowish discoloration. The displacement was reduced with some difficulty and the fragment of the posterior acetabular wall was at *such an angle that the screw* was placed close to the joint He was in traction for 10 weeks but subsequently developed absorption about the screw and evidence of avascular necrosis. In addition, the screw appeared to be making some pressure against the head of the femur itself. After 8 *months a vitallium cup arthroplasty* was carried out. Now after an additional 12



FIG. 2. (*Left*) Roentgenogram of the hip after reduction of dislocation, showing displacement of the posterior fragment of the acetabulum (*Right*) Appearance after open reduction and fixation of the posterior fragment of the acetabulum with a *single screw*

months he has occasional aching pain, with 80° flexion, 25° abduction and 10° rotation in each direction (Fig 3)

Of the other 2 patients one s fracture was only a fragment of the margin of the acetabular wall and he was treated in traction after reduction, followed by non-weight bearing for 4 months. He has normal function of his joint and still is working in a coal mine after 8 years The last patient was seen in a distant hospital It was a posterior dislocation with a small fragment, but there were other injuries Treatment by traction after reduction was advised The reduction was not maintained, as he was allowed to sit up and eventually arthrodesis of the hip was carried out.

Central Fractures and Dislocations

There were 12 patients in this group For the most part, these have been the result of accidents occurring in the coal mines *However one occurred in a white female* who fell from a second-story porch as she was doing her housecleaning. This group has been treated by traction, usually skeletal, for a period of about 10 weeks and then non weight-bearing for as long as 6 months

Open reduction with reposition of the floor of the acetabulum has not been attempted in this series Four of them have had injuries to the sciatic nerve and have been associated with other severe injuries, including fractures of the pelvis fractures of the shaft of the femur on the same side and injuries to other extremities

The white female who fell from her porch sustained an intrapelvic protrusion of the head of the right femur which was treated by traction in abduction for 10 weeks and then gradual weight-bearing After 4 years she has some pain and shows moderate restriction in motion. There is x ray evidence of loss of the joint space but clinically she has not had sufficient restriction to necessitate reconstructive surgery up to the present time (Fig 4)

The second interesting case in this series is a white male who sustained not only a central dislocation of the head of the femur *but also a fracture of the shaft on the same* side fractures of the sacrum and the lumbar spine and injury to the urethra. He was treated with traction through the trochanteric region to reduce the dislocations as well as to the lower leg for the fracture of



Fig 3 (Left) Roentgenogram after the initial open reduction of the posterior dislocation that had been present for more than a week. It is noted that the screw is lying close to the margin of the joint. There is narrowing of the joint space and beginning erosion of the articular surface (*Right*) After vitallium-cup arthroplasty



FIG. 4 (*Left*) Roentgenogram of the pelvis after prolonged traction showing a sat isfactory position of the head of the femur that formerly had been protruding into the pelvis. (*Right*) Appearance of the hip 4 years later showing marked loss of the joint space. However the patient showed surprisingly good movement clinically

the shaft. His other injuries were treated simultaneously He demonstrated a reasonably good result immediately after reduction and did not bear any weight for a period of 6 months Subsequently he has shown a gradual decrease in the joint space increasing roughening of the head of the femur and loss of motion until at the end of 2 years he showed almost complete re striction in motion and severe pain. He now has been treated by excision of the head which was found to be the site of severe arthritis with extensive panus formation and only a small central area of reasonably nor mal cartilage 1 cm in diameter The floor of the acetabulum was rough and irregular so that reaming was necessary A stem type prosthesis was inserted He now has been permitted complete weight bearing but has pain in the hip after short periods. This has decreased slightly after 1 year (Fig. 5) The range of motion in the hip is normal, but



FIG. 5 (*Left*) Roentgenogram of the pelvis after initial traction, showing the head still protruding partially into the acetabulum. A displacement in the sacro-iliac joint on the same side also can be noted. (*Center*) Appearance of the hip after healing of the acetabulum but before weight-bearing. (*Right*) Appearance of the joint at the end of 2 years, showing loss of joint space, roughening and irregularity of the articular surface and evidence of avascular changes.



FIG 6 (*Left*) Posterior dislocation, with a fragment of the head lying in the acetabulum. (*Center*) Appearance 3 days later prior to open reduction (*Right*) Appearance of the hip 22 months after reduction, showing loss of the inferior articular surface of the head of the femur with the joint space maintained in a fairly good manner after a year's weight-bearing. A considerable amount of calcification is noted in the superior capsule.

pain is severe enough to prevent return to his former occupation and he is now engaged in a sedentary job An arthrodesis would have prevented his pain but he could not have returned to work with a stiff hip

Dislocation with Fracture of the Head or the Neck of the Femur

There were 2 patients in this group both of whom required surgery

The first showed a complete posterior dislocation of the head of the right femur with a fracture through the base of the neck of the femur itself, which occurred when he was caught beneath a falling tree There were other injuries and he was in severe shock. It was impossible to consider extensive surgery on him until 5 days after the injury At that time the dislocation of the head of the femur was reduced and the fracture was fixed by a Smith-Petersen nail with a plate attached to the shaft of the femur *The fracture gradually healed with* tremendous overgrowth of bone and he has shown evidence of traumatic arthritis He has slight motion in the hip joint, which is not extremely painful after 14 years This injury was accompanied by a severe contusion of the sciatic nerve with permanent paralysis of the peroneal portion.

The second case was a white male who was injured in a car accident and sustained a severe head injury Because of this he had been given a spinal anesthetic at a distant hospital and two attempts at reduction were carried out before he was transferred to our hospital after 3 days Roentgenograms revealed the head to be lying posteriorly with a fragment of the head in the joint. Operation was carried out through a posterior incision. The fragment of the head, which was lying in the acetabulum, consisted of about one fifth of the inferior articular surface The head of the femur was dry and the articular cartilage showed the usual yellowish discoloration. After removal of the fragment the dislocation was reduced with a great deal of difficulty but reconstruction was not attempted at that time because of the patient's general condition and *the fact that the weight-bearing surface* was still intact He was treated in traction for more than 8 weeks and was on crutches for a total of 6 months It will be seen that following reduction the position was fairly satisfactory At the present time 22 months



FIG. 7 Early changes in the hip occurring less than 2 years after dislocation. Reduction had been delayed for 24 hours.



FIG. 8 Appearance of a hip 3 years after injury in which reduction of the posterior dislocation had been delayed for 24 hours.

after injury he shows a fairly marked degree of myositis ossificans with narrowing of the joint space. However, he has maintained a reasonably good range of motion in his hip with only slight aching pain and has returned to his regular occupation (Fig 6) Motion is restricted in internal rotation at 5° flexion at 80° and abduction at 25

End Results of Former Injuries

Of the patients with old injuries most were seen because of pain limitation of motion in the hip or deformity Many of them had been treated years before and their original roentgenograms were not available In these persons we found it necessary to rely upon the history from the patient or in a few instances from the doctor In some who had been treated more recently even within the past 5 years, we were unable to obtain more than confirmation of the story A few of the patients stated that they had been injured years ago and had been treated by a physician, either in his office or in the home where the hip was "pulled back into place," and they were allowed to become active at once.

This series of 38 patients whose injuries for the most part appear to have been either posterior or central dislocations record the persistent fact in the histories of many of them that reduction had been delayed anywhere from 1 to 3 days. Those in whom this fact was recorded have shown the most severe degree of disability at the present time. As a group they show from 50 per cent to complete loss of motion in the hip, with varying degrees of flexion and adduction contracture accompanied by pain and inability to walk except by the use of crutches Some of them have shown a rather marked degree of avascular necrosis and





FIG. 9 (*Left*) Bilateral traumatic arthritis in a patient who had sustained central fracture-dislocations of both hips 23 years before. (*Right*) Appearance of the hips after bilateral cup arthroplasty The hip on the right has shown a persistent anteversion of the head.



FIG 10 Two years postoperatively in a patient weighing more than 200 pounds Calcification can be noted in the superior capsule. He has a normal range of motion and has returned to his regular work in the coal mines.

thus has been noted in a few of the more recent patients even those who have been seen after 2 to 4 years. Others show a rather extensive degree of traumatic arthritis and 1 of them, extensive lipping which has limited his motion completely Six young patients were examined, all of whom were less than 17 at the time of accident As a group they show the most extensive changes in the hip joint.

A few of these patients have desired treatment of some sort and in this group there have been 16 arthroplasties, 9 having vitallium cups, 7 metallic prostheses and 3 arthrodeses



FIG. 11 Appearance after resection of the head and the neck and replacement with a Thompson type of prosthesis.

Reconstructive Surgery and End Results

For many years arthrodesis of the hip was considered as the eventual treatment in those persons who developed pain and limitation of motion following traumatic injury of the hip However in the presence of avascular necrosis healing was prolonged, and fusion was very difficult to obtain. If operation was delayed until avascular necrosis had reached its maximum degree of healing, fusion was possible to a more favorable extent but even in these patients fixation for as long as a year or more was often necessary and this resulted in additional disability to the knee and the entire lower extremity Fixation with a long pin or screw into the ilium has been tried with some improvement. Recently arthroplasty has been looked upon with more favor Particularly in this community where a person with a fixed hip joint would be unable to return to employment in the mines, it has been our feeling that if a movable joint relatively free from pain could be obtained, then these persons could be rehabilitated to a much better degree than those having a completely fixed hip

Of the patients who have had cup arthroplasties it has required from 6 to 12 months to obtain a reasonable degree of use in most of them but in those in whom we feel that a satisfactory procedure has been carried out, the range of motion has been good and the patient has been relatively free from pain. Of the 9 patients who have had vitallium cup arthroplasties, the results have been good in 5 fair in 3 and poor in 2 All of those in the first group have returned to their regular work, Aching pain is present to some degree after 8 to 10 hours of weight bearing. In those persons in whom the head has been lost or a portion of the neck involved, we have used metallic prostheses rather than accept a considerable amount of shortening by use of a cup To date these patients have shown reasonably satisfactory return of function and in 1 in whom we replaced one of his bilateral cups with a prosthesis,

it is his opinion that the most recently operated hip in which the prosthesis has been placed is the better of his hips although his motion still is limited 60 per cent and he has pain Of the others the results are good in 4 fair in 2 and poor in 1 because of pain. Of the patients with arthrodesis 2 are good with freedom from pain 1 never has fused completely and is painful but further surgery has been refused to date

COMPLICATIONS

The complications which have been seen in this series in addition to avascular necrosis and traumatic arthritis chiefly have concerned injury to the sciatic nerve In the anterior dislocation no injuries of the nerve have been noted. Two nerve injuries occurred in posterior dislocation and 4 following central dislocations None of these have been complete paralysis of the entire sciatic nerve but the peroneal branch has been involved in all of them There has been a slight degree of return of function in 2 to date but in the others including the complete displacement of the head, no return of function has been noted in from 2 to 14 years The sciatic nerve has been explored in 2 patients There was evidence of contusion of the nerve and neurolysis was carried out.

The occurrence of calcification in the capsule has been noted in those in whom the injury was moderately severe, especially where fracture of the rim was present It has not been noted in the simple dislocations either anterior or posterior that were treated by closed reduction. The appearance of myositis ossificans has been seen in several of those in whom surgery has been performed, all having been operated through a posterior incision This does not appear to have been severe enough to limit motion to any great extent in any of these persons

In dislocations of the hip the injury as well as the subsequent course is frequently dependent upon the severity of the initial trauma, both from the force of the blow and the extent of the displacement at the time Tearing of the ligamentum teres almost always occurs Tearing of the blood vessels or thrombosis of the vessels of the capsule and the posterior retinaculum at the time of injury frequently produces a severe loss of blood supply to the head of the femur This in itself is sufficient to cause early appearance of an avascular necrosis This is usually shown by slight mottling of the head of the femur with areas of both increased density and osteoporosis Narrowing of the joint space usually follows this with alteration in the head of the femur if weight bearing is not prevented The treatment of avascular necrosis to date presents a number of difficulties In 2 of these patients who were seen early drilling has been tried but it has not proved to be of value Stuck and Hinchey reported attempts to increase the blood supply to the head and the neck of the femur by transfer of muscle flaps but this has not received widespread acceptance [4] Arthrodesis in the presence of avascular necrosis is a very slow process

Trauma sufficient to dislocate the hip may severely injure the articular cartilage with the eventual occurrence of traumatic arthritis These changes may be delayed for a number of years and this presents a definite medicolegal complication, as a number of patients may develop severe disability sometime after the compensability of their injury has terminated. This in itself places a responsibility upon all who treat these cases as in a great number of them it often can be estimated that this is going to develop at a later date In central dislocations and fractures of the floor of the acetabulum traumatic arthritis has developed in almost 100 per cent of the patients to date

COMMENTS

Dislocation of the hip is an emergency and immediate reduction is imperative Repeated x ray views are sometimes necessary in order to rule out incomplete reduction

In fractures of the rim of the acetabulum reduction by closed manipulation is carried

out open reduction, if necessary can be performed when the patient's condition improves. Open reduction should be performed early on patients in whom closed manipulation is unsuccessful

In central fractures and dislocations or any severe injury of the hip it may be advisable to perform a vitallium cup arthroplasty at the original surgical procedure Once avascular necrosis is demonstrated, the patient shows a progressive deterioration of the joint and eventually traumatic arthritis Early arthroplasty might decrease the eventual period of disability as well as reduce the pain

When injury of the sciatic nerve persists more than a few weeks without improving exploration is indicated.

SUMMARY

From a study of this small series of traumatic injuries to the hip joint, it can be stated that if early and gentle manipulation of a simple dislocation of the hip joint is carried out, excellent results can be obtained. It would appear that immobilization for a period of 2 months followed by gradual resumption of weight-bearing, is as satisfactory a method of treatment as we have at the present time

In those persons in whom fracture of the margin of the acetabulum occurs accurate reduction of the dislocation as well as the fragments must be obtained immediately If the fragments are not replaced accurately or the joint surfaces closely approximated, open reduction should be carried out in order to obtain the best position possible When large fragments are present, exposure through the posterior approach is the most advantageous

In central dislocations the best results were obtained with prolonged traction in abduction but perhaps reposition of the floor of the acetabulum might be of some value in these patients Certainly the incongruity of the articular surface in these patients has given very unsatisfactory late results, with almost 100 per cent occurrence of traumatic arthritis of varying degrees.

When fracture of the head of the femur occurs it is best to avoid open reduction unless it is necessary to remove a fragment to obtain a reduction of the dislocation itself. When the head is both fractured and completely dislocated the occurrence of avascular necrosis is almost sure to follow

Frequently avascular necrosis can be detected early in those persons in whom it is going to occur, both because of a complaint of pain and the appearance of the hip in the roentgenograms. This should be determined at the earliest possible date in order to treat the condition if possible and so that the patient may be advised in regard to any future limitation that might affect his work as well as his disability evaluation.

Injuries to the sciatic nerve most commonly occur in the peroneal division If they persist more than a few months, they appear to be of permanent nature Early exploration was not carried out, and in view of the findings in the 2 patients who were explored, it probably would be advisable

Calcification in the capsule occurs occasionally in severe injuries and myositis ossificans is seen most frequently in those patients who have had surgery or marked displacement.

Arthrodesis in this series of cases has been carried out in only 3 patients, and the result of this procedure is not very satisfactory for those patients who are required to return to vigorous occupations.

Arthroplasty to date has not given completely satisfactory results but, for the most part the patients have been improved, and many of them have been able to return to their regular employment.

REFERENCES

1 Banks, S W Aseptic necrosis of the femoral head following traumatic dislocations of the hip a report of nine cases, J Bone & Joint Surg. 23 753 1941
2. Chandler S B., and Kreuscher P H A study of the blood supply of the liga

mentum teres and its relation to the circulation of the head of the femur J Bone & Joint Surg 14 834 1932

3 Funsten, R. V Kinser Prentice, and Frankel C. J Dashboard dislocation of the hip a report of twenty cases of traumatic dislocation J Bone & Joint Surg 20·124 1938

4 Stuck W G., and Hinchey J J Experimentally increased blood supply to the head and neck of the femur Surg Gynec. & Obst. 78 160 1944

5 Urist M R. Fracture-dislocation of the hip joint the nature of the traumatic lesion treatment, late complications, and end results, J Bone & Joint Surg 30-A 699 1948

6 ——— Fractures of the acetabulum the nature of the traumatic lesions treatment, and two-year end results, Ann Surg 127 1150 1948

7 Watson Jones Reginald Fractures and Joint Injuries, ed. 3 vol. 2 Baltimore Williams & Wilkins, 1943

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The Treatment of Congenital Dislocation of the Hip in Children Less than 5 Years Old

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Generally it is recognized that in cases of congenital dislocation of the hip the younger the patient is the more readily will he respond to treatment the older the patient is the more difficult it is to achieve a satisfactory result. This clinical observation is based on the fact that the soft tissues adapt themselves to the existing skeletal abnormality thereby increasing the formation of secondary alterations which are progressive in nature and aggravate the deformity In addition new functional demands produce adaptative alterations in the organs concerned this is particularly true of the skeletal system Hence it is reasonable to assume that restoration of normal anatomy is to be expected after correction of an abnormal situation.

The observations made by the author during open reduction for congenital dislocation of hips and those noted in follow-up studies reveal that failure to correct the causative factors responsible for the deformity especially aplasia of the acetabulum and anteversion of the femoral neck results in easy redislocation as well as residual subluxations of the affected hips. These observations together with the knowledge that many cases treated conservatively are failures and exhibit numerous complications justify the author in formulating certain *therapeutic criteria* which are set forth in this presentation.

The best procedure everything else being equal, is that which is most conservative this does not imply that surgery should be avoided when manual reduction is unsatisfactory nor does it imply that it should be resorted to when it is avoidable The choice of method is based on roentgenograms and arthrography which will show the soft tissue obstacles Such precautions will avoid false reduction and useless injury It is far better than the practice of some surgeons who carry on treatment over a period of months until failure is apparent and then decide that there is an indication for open surgery

Manipulative therapy is ideal, provided that these maneuvers do not injure the delicate articular cartilage or the femoral epiphysis Reduction should be carried out by gentle maneuvers and should be maintained without excessive femoral acetabular pressure It should be remembered that, on the whole success depends greatly on a well-centered head within the cotyloid fossa.

Open reduction should solve the problem in toto in avoiding redislocations, residual subluxations undue pressure of the femur within the acetabulum the need for further surgery and the loss of time in returning normal function to the hip joint. However, surgical procedures should be viewed as aggressive thus, they should be resorted to only when it becomes apparent that the force necessary to achieve reduction will be excessive This degree of force is difficult to determine because it is an individual and personal factor When

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in doubt as to the procedure of choice or when concentricity is lacking after reduction, one should resort to open methods These will serve to restrain the attack on soft tissues at the points of election and under direct surgical vision however any unnecessary operative measures should be avoided.

Simple open reduction with reconstruction of the soft tissues by layers is the ideal surgical procedure. It might be necessary to operate on soft tissue structures only but this is usually insufficient because the acetabulum may be aplasic the femoral head out of proportion to the acetabulum or the femoral anteversion very pronounced, or there may be a high femur which cannot be brought down despite total capsulotomy and finally because of muscular shortening. In such cases the author's choice is, respectively to deepen the cotyloid to enlarge it and to carry out a subtrochanteric osteotomy or a partial diaphysectomy In substance the problem is solved by correcting the dislocation as physiologically as possible in one procedure

In reading Leveuf's book, *Les luxations et subluxations congénitales de l'hanche* the author admired his philosophy and his technic served as groundwork to build the author's line of operative action with the modifications set forth in this paper Arthrography follows Faber's method to which has been added control with a screen. The surgical approach is a cross between Ombredanne's and Zahradnicek's method a subtrochanteric osteotomy is performed, and the femoral segments are fixed by an intramedullary nail, thereby leaving a greater blood supply for the proximal segment. The level of the bone section has been recommended by Hey-Groves Swett, Ombredanne and Zahradnicek. Reconstruction of the fossa and the covering of the femoral head with the capsule followed procedures advocated by Codivilla Hey-Groves and Colonna

Correction of anteversion and maintenance of the femoral head within the recess of the cotyloid is achieved by an extra-articular nail in the superior extremity of the femur which then is placed in internal rotation in relation to the ilium, the limb is placed in slight external rotation until bony union of the subtrochanteric osteotomy takes place This is followed by the application of a brace which makes traction on and holds the limb in internal rotation, the thighs are free for flexion and extension. Regardless of the method of reduction, it should be done under roentgenographic control in order to guarantee correct placing of the articular surfaces Periodic roentgenographic control will ensure that the iliofemoral relation has not been modified.

Years ago cotyloplasty was done (butée" for the French, "shelving" for the Anglo-Americans) logically and hopefully The author's experience and the results observed in cases done by famous orthopaedists have disheartened him because the graft frequently fractures displaces or is reabsorbed. This is more likely to occur in the younger patient. Moreover the femur often is left laterally displaced. In cases showing acetabular flattening it is the author's opinion that, generally speaking arthroplasty with deepening of the cavity is the lesser evil To date, results following this procedure have been quite good

Bifurcation osteotomy is a stabilizing procedure which improves the shortening and the strength of the abductor mechanism and also provides an artificial support however it is palliative The angle of support frequently lessens and has to be repeated. This operation often is a cause of limping, limitation of motion pain and genu valgus

Fusion is a good stabilizing operation but should be performed only when no other choice remains, since immobility produces limping It never is indicated in children, neither is it indicated in the presence of lumbar pathology nor can it be carried out on more than one side

Time of Operation. The author's small surgical experience has fully convinced him that the femoral head deformities the wax drop osteophyte formation of the inferior pole the pitting, the loss of luster the in

creased acetabular aplasia and the increased plane of the cotyloid rim, the capsular ad hesions to the ilium the neck and the femoral head, the drumhead constriction of the cotyl oid fossa by the capsule, by the iliopsoas or by the transverse ligament, the hour-glass constriction of the capsule, the hypertrophy of the ligamentum teres etc all are secondary to the dislocation per se just as are muscular wasting, shortening of the limb and scoliosis

Repeated frequent or forced manipula tions cause or accentuate these changes Leveuf has wisely pointed this out and also the relative ease of treatment and improved prognosis when treating virgin hips The author concurs in this and considers it unwise to wait until a later date to carry out reduc tion when the secondary changes are pronounced and the response to the formation of the fossa will not be as marked or as good as when done at an earlier age

ROENTGENOGRAPHIC STUDY

Regular roentgenograms and arthrography are used to avoid useless and harmful manipulations and immobilization in those cases where closed treatment is not feasible How ever one should bear in mind that no patient should be operated upon without a just indi cation and without all the facts gleaned from a roengenographic survey Because an anter oposterior film fails to reveal all the available data the following views are recommended

1 Anteroposterior plate with maximum internal rotation to show the neck length and the cephalad ossifying center This view is taken of both hips and in like positions.

2 Lateral plate of both hips in patients more than 12 months old following Sanchis Olmos technic with the patient seated and each thigh abducted to 30 to 35 from the mid-line The cassette is placed vertically against the patient s back (Fig. 1) the central ray passes horizontally in line with the pubis The legs hang freely over the edge of the table making sure that there is no ligamentous laxity or lateral deformity of the knees before taking the plate Under these conditions, the femurs are found to be rotated to a neutral position there is an angle of declination of the femoral neck equal to 25° in a normal child as measured from a horizontal plane corresponding to the femoral shafts Thus, approximately and with little difficulty or complications or instruments beyond the means of orthopaedist, anteversion is measured this is a most important step when deciding whether or not a derotation osteotomy should be done This lateral plate projects the cotyloid fossa on a different plane as the pelvis is tilted slightly forward

3 Besides the two plates already mentioned, arthrography is done in children more than one year old, which permits visualization of the articular terrain not permitted by the radiotranslucent soft tissue This step of the roentgenographic examination is indispensable and the author does not treat a congenital dislocation of the hip without first doing it. It is done under anesthesia to keep the child quiet and to carry it out without pain at the same time, subcutaneous adduc tor tenotomy is performed when the femoral head is displaced above the rim of the acetabulum

Technic. The anesthetized patient is placed on an orthopaedic table in the supine position An anteroposterior view is taken of the whole pelvis with both lower limbs in internal rotation A wire grill is placed over the groin (or both hips if the dislocation is bilateral) and another exposure is made The point corresponding to the intersection of the acetabulum with the Y cartilage is marked on the skin by inserting a hypodermic needle perpendicularly to the groin While an assist ant holds both lower limbs in moderate internal rotation the surgeon inserts a long needle in the lateral aspect of the thigh in front of the femur aiming toward the needle forward or backward, recalling that the ante rior border of the acetabulum in infants suf fering this ailment is less than 2 cm behind the antero-inferior spine Another roentgenogram is taken A syringe with 10 cc. of saline solution is connected to the lateral needle, and 1 or 2 cc injected. The same amount of liquid must be withdrawn if the needle has

penetrated the joint. When this occurs, the solution is taken out and a radiopaque aqueous solution is injected from 2 to 5 cc. is injected, depending on the age of the patient. The needle is withdrawn the groin is massaged gently the hip is moved in all directions, and then another roentgenogram is taken If the femoral head is at a higher level than the acetabulum a subcutaneous tenotomy of the adductors is performed, then reduction of the head by gentle manipulation is tried

If the dislocation can be reduced correctly without force, a cast is applied in the position obtained If reduction is impossible and there are no apparent soft tissue obstacles

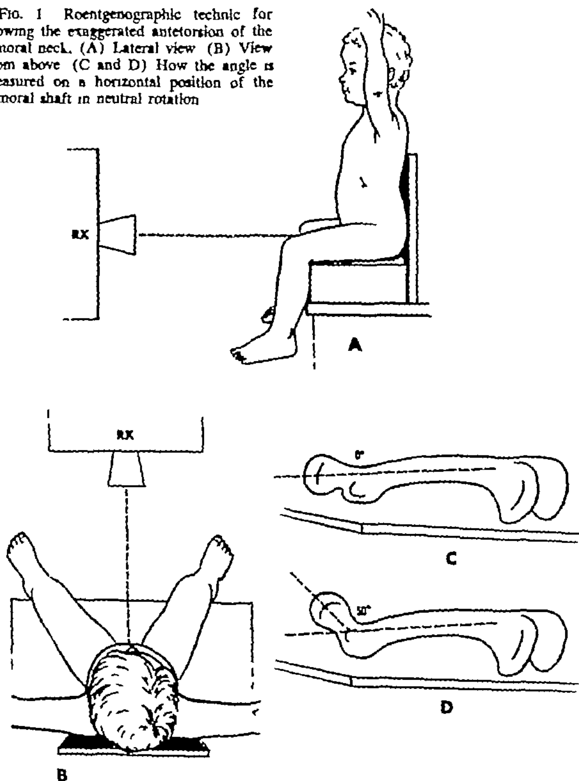


FIG. 1 Roentgenographic technic for showing the exaggerated antetorsion of the femoral neck. (A) Lateral view (B) View from above (C and D) How the angle is measured on a horizontal position of the femoral shaft in neutral rotation

preventing reduction, heavy adhesive or sponge rubber traction is used until the head descends to its proper level after which the author's brace is fitted.

Obstacles. The soft tissue obstacles to reduction or those mentioned previously which oppose correct maintenance are shown in Figure 2 These contingencies as well as the roentgenographic revelations of the pitch of the cotyloid roof the flattening of the cavity and the pronounced elevation of the *femur or its marked anteversions, are all* factors which determine open reduction

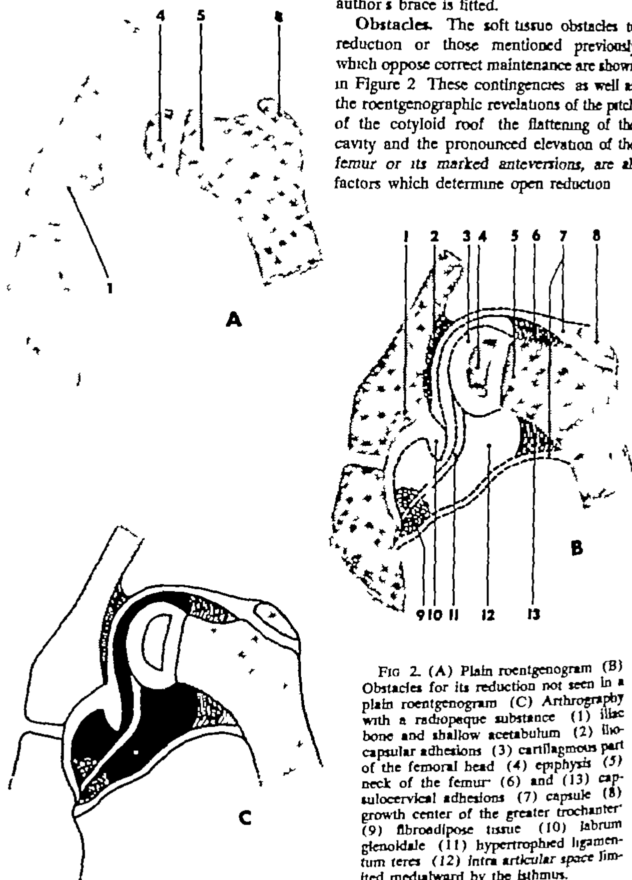


FIG 2. (A) Plain roentgenogram (B) Obstacles for its reduction not seen in a plain roentgenogram (C) Arthrography with a radiopaque substance (1) iliac bone and shallow acetabulum (2) iliocapsular adhesions (3) cartilaginous part of the femoral head (4) epiphysis (5) neck of the femur (6) and (13) capsulocervical adhesions (7) capsule (8) growth center of the greater trochanter (9) fibroadipose tissue (10) labrum glenoidale (11) hypertrophied ligamentum teres (12) *intra articular space* limited medialward by the isthmus.

CLOSED REDUCTION

Children Less Than 4 Months Old In these cases, excepting those of primary dislocation with an elevated femur or severe aplasia of the acetabulum results gained with the use of a Frejka cushion are excellent as long as one counts on the intelligence and the fine co-operation of the parents After this age, results range from poor to bad. Its use should be discontinued only when improvement is stationary as shown by periodic roentgenographic studies The author's experience is scant with this age group

Children from 4 to 12 Months Old. In cases showing an elevated femur it is advisable to apply adhesive or sponge rubber traction this is suspended when it is no longer useful. One should try progressive reduction by means of the author's reduction brace or particularly with Paci-Lorenz method of gentle manipulations Casts should be used at first, including the feet, in order to prevent rotation, leaving the knees free after 3 months If roentgenograms show an incomplete reduction or a poorly centered head it is better to use the author's apparatus Cases of subluxation in children less than 1 year old should be treated as though they were dislocated.

Children from 12 Months to 5 Years Old These cases should be studied systematically by roentgenograms, including arthrography which will decide the plan of therapy to be followed according to the dislocation At the time of the arthrography if the femur is higher than the cotyloid, an adductor myotomy on the the affected side always should be done If a bilateral dislocation exists the myotomy is done on the side on which reduction is first contemplated. This simplifies closed reductions or if surgery is to be chosen it enhances traction. Traction on both lower limbs at the same time is not advisable in bilateral dislocation because the weight of the child is not sufficient for countertraction.

Cases are encountered in which closed reduction is successful and is maintained without a brace but anteversion is still marked. In such instances a derotation osteotomy should be done The proximal fragment is fixed at the level of the trochanter by means of a transcutaneous pin maintaining it in 10° of internal rotation. A cast is applied holding the limb distal to the osteotomy site in 10° of external rotation The site of the osteotomy can be in the supracondylar region or the subtrochanteric the author favors the latter because the line of force of the pelvicrural muscles is not disturbed

The author's experience shows that evidence of sclerosis of the cotyloid rim points toward a poor prognosis because it indicates that the fossa is not inclined to reduce its angle

Farill's Brace. This brace was introduced in 1948 to be used during the convalescent stage of open reduction of congenital dislocation of the hip Its object is treatment in abduction and internal rotation at the same time traction downward and medially of the proximal fragment of the femur is accomplished while flexion and extension of the hips are permitted thus enabling the little patients to sit up This movement is of great importance since it helps the femoral head to deepen the cotyloid cavity

The author observed that in his series the nucleus of the femoral head and its ossification developed more rapidly than in the cases treated in plaster in the frog position. The latter cases frequently show osteochondritic complications. This position causes circulatory disturbances of the superior femoral epiphysis as observed by Nicholson.

When there is marked anteversion, which was noted in a large number in the author's series, and there is hypoplasia or aplasia of the anterior rim of the cotyloid, there is *special need* for internal rotation of the hip in order to prevent redislocation. This is noted readily at operation.

Any surgeon who has performed a hip arthrotomy recalls the softness of the femoral cartilage, which on the least scraping or pressure of an instrument leaves a bloody mark Injuries which are produced with closed forced or repeated manipulations must of ne

cessity leave a mark which may not be perceived immediately because of the radiotransparency of the cartilage However this will show up later when an arthrotomy is done or during later treatment.

It is indispensable and urgent that atraumatic reduction be achieved before the secondary changes have become established and complicate the treatment and the prognosis Conservative methods should hold preference over open ones when indicated and not harmful but if the contrary holds there should be no hesitation and surgery should be considered immediately upon finishing the case study perfection in reduction should be sacrificed to conservatism

In June 1949 after 3 weeks of unsuccessful skeletal traction to lower the level of a femur in a bilateral dislocation the author applied his brace and was surprised to note that both sides were reduced in 11 days Since then he uses it in closed reductions when arthrography shows the possibility of doing so without operation. If the obstacles presented by the soft tissues indicate the contrary if the joint cavity is flat or the roof too oblique it is preferable to operate. In subluxation, the author's brace is recommended as the conservative measure of choice used over several months This is followed by roentgenographic control, operative intervention is justifiable if reduction cannot be maintained

It should be remembered that any lengthy immobility of the hip produces laxness of the knee ligaments, with resulting instability In order to prevent this the author recommends that his brace or any other should not be worn continuously for more than 2 months After this knee movements are allowed, gradually tricycle riding, morning and afternoon is permitted The brace is used in the interim. No walking under any circumstances is allowed until improvement is well advanced.

DESCRIPTION The author's brace (Fig 3) maintains abduction similar to Putti's de-

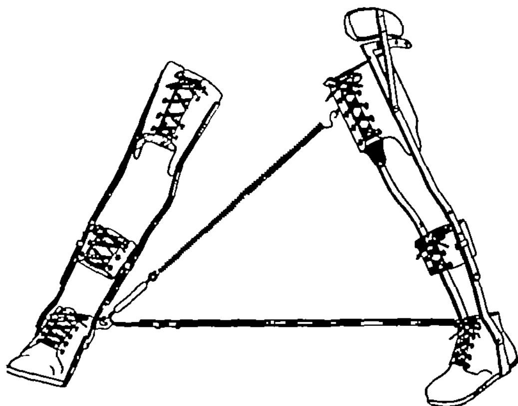


FIG. 3 Farill's apparatus for convalescence and closed reduction Notice the trochanteric plate the telescoping abduction bar and the spring for adducting and lowering the femur

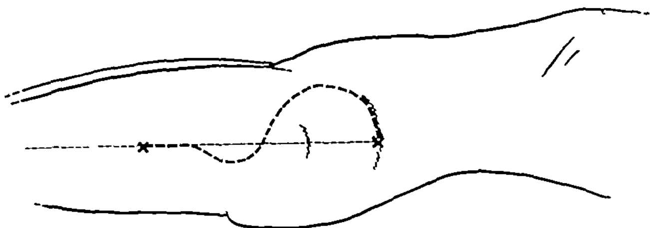


FIG. 4 Surgical approach used for open reduction

varicator in addition it produces internal rotation with traction downward and medially while it permits flexion and extension of the hips It is a lever of the third gender where the force applied by a spring intervenes between the resistance offered by the dislocated hip and the fulcrum which is situated over the hinge of the abduction bar on the ankle of the same side

The brace comprises 2 metal rods for each limb extending from the base of the thighs to the stirrup applied to the shoes, permitting free flexion and extension at the ankles The knees are fixed at 180° At the upper end of the lateral rod a metal plate covered with sponge rubber is placed to give pressure over the greater trochanter At the upper end of the medial rod a spring is attached to a ring, graduating its tension with a turnbuckle which is attached by its opposite pole to the abduction bar near the opposite ankle This bar can be telescoped and is affixed to the lower part of the medial rods above the joint of the ankles by 2 hinges. On the dislocated side the hinge carries a stop which prevents external rotation but leaves internal rotation free The pressure produced by the spring should be moderate and is regulated according to the patient s tolerance periodic roentgenographic readings are taken the first few days. The nurse should be instructed to watch and adjust it during the day In bilateral cases the same appliance is used for both limbs the spring traction is increased by means of weights that act through the same rings as do the springs Countertraction is applied by elevating the foot of the bed.

OPEN REDUCTION

Preoperative Regimen If the femur is above the cotyloid fossa strong skin traction is applied 2 to 3 weeks prior to surgery in order to bring it down and to stretch the muscles The difficulties in bringing the femur down and the time required should be borne in mind during the operation In cases requiring a long time and strong traction one may expect some recovery of muscle tone after reduction is achieved. This will be manifested by the excessive pressure between the femoral head and the cotyloid and is avoided solely by diaphysectomy

Operative Procedure. *After having decided upon open reduction based on clinical roentgenologic and laboratory studies one should go to the operating room determined to solve the problem of the dislocation completely at the one sitting and then await the necessary biologic reactions which consolidate the surgery performed*

PLACING THE PATIENT The child is placed face up on an orthopaedic table which is adapted for anteroposterior roentgenographic control. The patient is placed over the pelvic rest, and both lower limbs are in neutral rotation with 20° abduction and with exactly enough traction to keep the patient set.

INCISION The author wishes to empha-

size his viewpoint that a complete exposure is required for this operation i.e. one which permits absolute liberty during surgery After trying Ollier Murphy's, Ombredanne's and Zahradnicek's incisions, a combination of the last two has been used since 1952 (Fig 4) One starts over the iliac crest in line with the vertical axis of the femur carrying it forward to the anterosuperior spine then it follows the anterior border of the gluteus medius, as does Ollier's incision to 2 fingerbreadths below the point of the trochanter reaching the superior part of the femoral shaft and then coursing it downward for a distance of from 6 to 8 cm. All small vessels are clamped off, the aponeurosis is incised over the iliac crest reaching bone and the opening is extended to the plane separating the tensor fascia femoris and the glutei as far as the base of the trochanter here the strong aponeurosis of the gluteus maximus is cut. A thin osteocartilaginous wafer is lifted from the trochanter together with the insertion of the gluteus medius and minimus and then the capsule is then uncovered up to the ilium. With a wide periosteal elevator it is separated with the gluteal insertions from the wing of the ilium, uncovering the cotyloid ridge The whole flap is covered with a warm saline-soaked sponge and is fixed to the skin over the crest by means of a towel clamp exposing the articulation without the need of an assistant. The tensor fascia femoris is incised transversally below its pelvic insertion anchoring its distal end with black silk The reflected tendon of the rectus is transected and the capsule is freed with its adhesions to the ilium. Internal and external rotation of the limb may be observed while the iliopsoas is retracted medially

Capsulotomy Once the dissection of the capsule is accomplished, especially the circumference visible on external and internal rotation of the femur a transverse capsulotomy is made on its anterior and superior aspect, paralleling the acetabular border leaving a small fringe marked off in order to reconstruct the capsule if necessary Through this opening, the inside of the capsule the femoral head and, if possible the cotyloid fossa is explored. Frequently the capsular isthmus adheres itself on the inferior border like a curtain or the iliopsoas over the cotyloid does not permit visualization of the fossa. If the lumen of the capsule is sufficient and the femur can be brought down without force to the level of the cavity the obstacle of the soft articular tissues is treated and the dislocation is reduced. If the length of the capsule permits the capsule is sutured to the fringe left over the acetabulum, which, as has been noted in the author's series has been the exception. As a rule the exploration cannot be done correctly and the femur cannot be brought down easily to the level of the fossa Under these conditions the capsulotomy is done completely around, leaving an over all length sufficient to cover the femoral head if necessary, a purse-string suture is used, following the orthoplastic technic of Codivilla, Hey-Groves and Colonna.

Intra articular Exploration Using a Lambotte hook an assistant carries the superior end of the femur laterally while another assistant retracts the anteromedial structures over the iliopsoas When doing this step it is convenient to grasp the edges of the cut capsule with Allis clamps, because this reference is an important guide to the cotyloid, which is difficult to find if one is not sufficiently experienced. The capsule is incised when found interposed like a drumhead over the acetabulum after separating it from the iliopsoas this is lengthened. This should not be done unless necessary because together with the abductor muscles, it is essential in maintaining reduction

If the ligamentum teres is found to be hypertrophied it is cut flush with the femoral head then it is grasped with strong forceps and cut out from the bottom of the fossa. If it is required, the same is done with the limbus and the transverse ligament the cavity is cleaned carefully of fibroadipose tissue which at this age except in one case

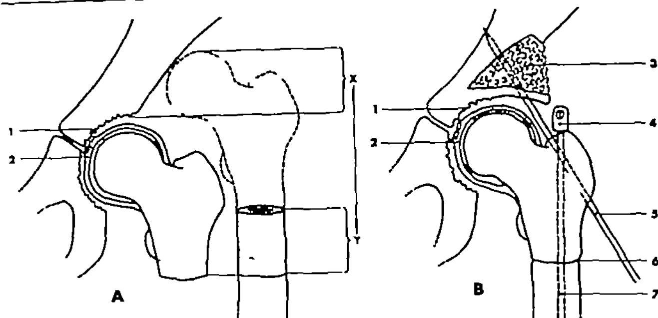


Fig 5 (A) Capsular arthroplasty and diaphysectomy in an irreducible dislocation with high femur The amount resected "Y" is equal to the upper displacement "X." (B) Capsular arthroplasty after osteotomy or diaphysectomy already nailed (intra medullary) with the anteversion corrected and a shelf made (1) Reamed acetabulum. (2) Capsule. (3) Shelf and bone chips (4 and 7) Steinmann nail with its screw protector cap (5) Lateral pin for fixing the reduction in correct rotation. (6) Osteotomy or diaphysectomy site

never has been enough to impede reduction. Then applying table traction as well as internal rotation movements one can see whether the femur descends easily and whether reduction may be achieved

Subtrochanteric Osteotomy This step (Fig. 5) must be done under vision and is of vital importance since it not only lengthens the femur but also prevents redislocation. Rarely is subtrochanteric osteotomy not done, because in the absence of abnormal anteversion, reduction is easy if the joint cavity is deep and the roof is slanted normally The osteotomy is done through the fibers of the vastus lateralis, 3 cm below the lesser trochanter The proximal fragment is grasped with Lane forceps or lion clamps in order to explore the cavity adequately As a rule reduction can be achieved without force The proximal fragment preserves the muscular insertions of the gluteus maximus, the pelvitrochanteric external rotators and the vastus lateralis If on reduction one observes over riding of the fragments at the osteotomy site the excess from the distal fragment is removed, thus avoiding undue intra articular pressure Diaphysectomy does not increase shortening because an equal or a lesser length is resected than the interval between the femoral head and the cotyloid rim (Fig 5A)

Treatment of the Joint Cavity When the acetabulum is not deep enough one may follow two courses, depending upon the degree of flattening (1) If the cavity is slightly insufficient and the angle of its roof not too far removed from the normal, one may do a cotyloplasty by bringing down an osteocartilaginous flap from the roof proper and filling the remaining defect with bone chips (2) If the flattening is severe, increasing subluxation, it is preferable to deepen the acetabulum with a large curet and an electric burr until its floor can be dented by a finger as advised by Colonna Care should be taken in forming the angle of the roof of the altered cavity Also an effort must be made not to enlarge excessively the cavity superiorly because this will preclude proper centering of the femoral head within the

acetabulum In the hands of the author this arthroplasty has given incomparably better results than cotyloplasty because in the latter the grafts displace reabsorb angulate or fracture This is particularly true in the very young patients With the fossa sufficient to take the head of the femur the capsule is closed over it with a purse-string suture after the excess length or thickness is removed in order to facilitate replacement of the head. Occasionally, the capsule is 1 cm in thickness at this point.

INTRAMEDULLARY NAILING A 3/16 in. Steinmann pin of proper length is passed through the canal of the proximal fragment, starting at the osteotomy site upward until it is flush with the cut bone Care is taken to have an assistant guide the nail in order that it may project from the skin near the iliac crest The osteotomized fragments are reduced, and the pin is driven down into the canal of the shaft of the femur leaving 2 cm of the nail protruding above the greater trochanter If only 2 cm are left protruding from the femur the nail will not impinge on the ilium when the thigh is abducted. The reduction is checked, and good contact is ensured at the osteotomy site The author has found it advantageous to use an end cap as in Figure 5B which permits its easy extraction.

FIXING THE REDUCTION AND CORRECTING ROTATION *One of the most difficult problems is maintaining the femoral epiphysis within the joint when it has a tendency to project itself outward* Hey-Groves in 1927 had described a step in his arthroplasty technic whereby the capsule was sutured over the head of the femur and anchored to the bottom of the acetabulum with a tendon suture It is the only surgical treatment which the author has found in the literature to prevent subluxation

The author fixes proper internal rotation with a ⅛ in pin in the proximal fragment, piercing it from below the greater trochanter and bringing it out over the superior margin of the neck to enter above the cotyloid (Fig. 5B) and then places the lower limb in 10° external rotation The free end of the pin is held by an assistant who simultaneously presses over the greater trochanter The nail is encased in plaster It is advisable to put the pin through the skin and not the wound

COTYLOPLASTY In cases of moderate subluxation due to an unduly oblique acetabular roof, cotyloplasty is indicated The author performs Gill s operation, reinforcing the bony shelf with a bone bank graft. These grafts are fixed with the pin used to fix internal rotation as described previously The pin is withdrawn 4 or 5 weeks later when the cast is removed and Farill s brace is applied. This procedure is indicated mainly in adolescence or adulthood since the grafts tend to become reabsorbed or to displace in the younger patients When dislocation is severe it is better to do an arthroplasty covering the head with the capsule and deepening the joint.

Plaster Cast. A double plaster spica is applied

Postoperative Care. Besides the routine postoperative care in major surgery a blood count on the first postoperative day and 5 days later is recommended The cast permits changing the patient's position Penicillin and dihydrostreptomycin are given as a safeguard for 72 hours morphine for pain the first 24 hours then phenobarbital-antipyrine. Control roentgenograms are taken before and after applying the cast at the end of surgery at the the end of the third day and every week thereafter Low fever reaction frequently is due to the presence of the pins, subsiding when the pins are withdrawn The lateral pin is withdrawn through a window cut in the cast at the end of 4 or 5 weeks and the intramedullary one is removed when callus is discernible at the osteotomy site. When this callus is visible on roentgenograms the cast is bivalved, and the brace maker measures the patient for the author s brace When the brace is ready it is applied without changing the position of abduction. One month later the use of a tricycle is permitted, as well as underwater exercises, trying not to carry the thigh in adduction except slowly and gradually Walking first

is permitted in the tank and then out of it, using a flat Thomas heel to force internal rotation The use of Farill s brace should be continued for some time at night When there is inequality of limb length, roent genographic measurement should be done, following the author's technic, and an appropriate lift is applied to the shoe of the short limb

Results. The follow-up has been too short to give final results. The author per formed the first operation using diaphysec tomy in 1946 hence many cases are still recent. In general, the immediate results have been very encouraging In further publications details regarding late results will be given.

STATISTICS OF PROCEDURES EMPLOYED

Number of patients treated		34
Number of hips		42
Total closed reductions		9
With Paci Lorenz technic	5	
With Farill s brace	4	
Total open reductions		33
Plain reductions	6	
With shelf added	2	
With capsular arthroplasty	4	
With diaphysectomy	6	
With arthroplasty and diaphysectomy	4	
With diaphysectomy and shelf	3	
Shelf operations with no reduction	8	
Total shelf operations	13	
Total diaphysectomies	13	
Total capsular arthroplasties	8	
Fatal cases (hyperpyrexia and pallor syndrome)	1	

CONCLUSIONS

1 The early diagnosis and treatment of congenital dislocation of the hip permits bet ter and faster results with simpler and less aggressive methods.

2 Arthrography and *lateral roentgenograms* are recommended routinely in chil dren more than 1 year old in order to select the method for reduction.

3 The author describes a brace for convalescence and gradual reduction in cases of subluxation and in some early cases of dislocation. This brace provides abduction, internal rotation and downward and medial traction of the femoral head, permitting free flexion and extension movements of the hip

4 One should strive for easy reduction, leaving zero pressure i e leaving no abnormal pressure of the femur on the acetabulum In order to accomplish this one must not hesitate in choosing operative procedures when necessary

5 Open procedures should be reserved for cases where closed reduction fails or when closed reduction is impossible as shown by arthrography

6 Surgical measures should be carried out before secondary femoral and cotyloid changes and deformities appear and when there is still sufficient time for the femoral head to remain normal following reduc tion (between the first and the fifth year)

7 On doing open reduction all the problems presented should be treated with minimal damage to the joint elements surgery should be definitive The convalescing pe riod is reduced, and there are more probabilities of gaining normal function sooner without complications.

8 In the open reduction of congenital dislocation of the hip the author recom mends subtrochanteric osteotomy as a must this prevents redislocation and corrects the antetorsion In cases showing a high femur one should resect the overriding section from the inferior segment after reduction thus preventing excessive intra-articular pressure

9 In the majority of cases showing moderate subluxation and a cotyloid roof not too oblique and not amenable to treatment other than surgery a cotyloplasty can be performed, but the author is much in favor of arthroplasty covering the head with the capsule this is also true in cases with a shallow acetabulum

10 Surgery for congenital dislocation of the hip should be undertaken by experienced surgeons in order to attain the best anatomic physiologic results and to avoid serious surgical complications

REFERENCES

Barcikowski, W Zasady operacynej stabilizacji stawu biodrowego we wrozonym zwichnieciu biodra u dzieci (Principles of operative stabilization of the hip in C.D H in children) Pamietnik X Zjazdu Polskiego Towarzystwa Ortop i Traumatol. 17:104 1953

Bojko M Osteochondritis po operacjach wrodzonych zwichniec stawu biodrowego (Osteochondritis following operations for congenital dislocation of the hip) Pamietnik X Zjazdu Polskiego Towarzystwa Ortop I Traumatol. 17.55 1953

Cheynel, J Recherches sur la physiopathologie de l'hanche Rev orthop 33 7 1947

Codivilla, A Contributo a la tecnica della cura cruenta della lussazione congenita dell'anca, Reforma med Roma 17 638 1901

Colonna, P C An arthroplastic procedure for congenital dislocation of the hip J Bone & Joint Surg. 20 604 1938

—— Congenital dislocation of the hip in children and adults, Am Acad. Orthop Surgeons, Instructional Course Lectures 8 169 Ann Arbor Edwards, 1951

Faber A. Untersuchungen über die Aetielogie und Pathogenese der angeborenen Hüftverrenkung, Leipzig Verlag G Thieme, 1938

Farill, J Reducción de la luxación congénita de la cadera en los niños, Paper presented before the Academia Nacional de Medicina México February 11 1948

—— Treatment of certain irreducible congenital dislocations of the hip in infants, Medicina 29:283 1949

—— El tratamiento de la luxación congénita de la cadera en niños menores de 10 años, An. ortop y traumatol. 3.281 1950

—— Orthoradiagraphic measurement of shortening of the lower extremity M. Radiog & Photog. 29-32, 1953

Feci, L. Patologia dell'anca, Edit. Nicola Zanichelli, XVI Bologna, 1938

Frejka, L. Paper American Academy of Orthopaedic Surgeons, Chicago 1947

Garlicki, M Operacyjne Leczenie Wysokich Wrodzonich Zwichniec Stawu Biodrowego (Operative treatment of high dislocations of the hip) Pamietnik X Zjazdu Polskiego Towarzystwa Ortop i Traumatol 17 55 1953

Grospic, F Open reduction of high congenital dislocation of the hip Proc. Soc Internat. Chir Orthop e Traumatol., 643 Brussels Liliens

Gruca, A Operacyjne Leczenie Wrodzonych Zwichieg Biodra (Operative treatment of the congenital dislocation of the hip) Pamietnik X Zjazdu Polskiego Towarzystwa Ortop i Traumatol. 17 5 1953

Haas, J Congenital Dislocation of the Hip, Springfield, Ill Thomas, 1951

—— Newer trends in the treatment of old congenital dislocations of the hip J Internat. Coll. Surgeons 20-667 1953

Hey-Groves, E. W Some contributions to the reconstructive surgery of the hip Brit. J Surg 14.486 1927

Howorth M B Congenital dislocation of the hip Ann. Surg 125 216 1947

—— Congenital dislocation of the hip technic of open reduction, Ann. Surg 135:508, 1952

Howorth, M B., and Smith, H. W Congenital dislocation of the hip treated by open reduction J Bone & Joint Surg 14 299 1932.

Leveuf J., and Bertrand P Luxations et subluxations congénitales de l'hanche Paris, g Doin 1946

Malawski S Hemiartropastika sposobem Codivilla-Colonna w leczeniu wrodzonego zwichniecia biodra, Pamietnik X Zjazdu Polskiego Towarzystwa Ortop i Traumatol. 17 37 1953

Marziani, R. Studio anatomico della lussazione congenita dell anca ridotta, Milan, Casa editrice Ambrosiana, 1947

Massie, W K., and Howorth, M B Congenital dislocation of the hip result of open reduction as seen in early adult period, J Bone & Joint Surg 33 171 1951

Memmi R. La patologia dell anca dopo riduzione di lussazione congenita, Roma, Editrice Universitas, 1947

Nicholson, J T Kopell H P and Mattel, F A. Regional stress angiography of the hip, Paper presented before the American Academy of Orthopaedic Surgeons, Chicago 1953

Ortolani, M La lussazione congenital dell'anca, Bologna, Capelli Edit., 1948

Ponseti, I. Causes of failure in the treatment of congenital dislocation of the hip J Bone & Joint Surg. 26 775 1944

—— Pathomechanics of the hip after the shelf operation J Bone & Joint Surg. 28 229 1946.

Rivarola, J E., and Pique A A Tratamiento de la luxación congénita de la cadera, Buenos Aires, Edit. El Ateneo 1948

Sanchis-Olmos, V Coxa valga, Cir ap locom. 7 318 1950

Scaglietti, O (Results of the early treatment of C.D H) Proc Soc Internat Chir Orthop. e Traumatol. 219 Brussels, Liliens, 1948

—— Surgical reduction of congenital dislocation of the hip anatomy technic, end results, Paper American Academy of Orthopaedic Surgeons, Chicago 1953

Steindler A., Kulowski J., and Freund, E. Congenital dislocation of the hip statistical analysis, J.A M.A 104 302, 1935

SECTION II

GENERAL ORTHOPAEDICS

8

Fundamentals of Design as Applied to Bone Surgery

DUNCAN C MCKEEVER, M D , F.A C S *

Engineers and industrial designers have carefully studied and analyzed the relation between structural form and functional strength of static and dynamic units in build ings and machinery from the tallest sky-scraper to the smallest watch mechanism. The vital importance of microscopic cracks and nicks incident to fabrication as weaken ing factors in the strength of machine parts subjected to stress has been known and studied extensively for many years. Books on this subject as applied to structural ma terials were written as early as 1858 and one very incomplete bibliography on the subject covers more than 30 pages of one reference book. These facts have been more or less ignored by orthopaedic surgeons and little if any effort has been made to apply this knowledge to the problems of bone surgery A brief study of the subject will convince any experienced orthopaedic sur geon that many failures in a wide variety of operative procedures are easily attributable to ignorance of the physical principles in volved and immediately one can begin to think of specific cases in which a lack of this knowledge resulted in failure

For years a fair percentage of fractures through the donor site in the tibia have been accepted as incident to cortical bone grafting and in many clinics casts were applied routinely to protect the donor area No one ever made any particular effort to determine why these fractures occurred and whether or not they could be avoided or prevented They can be, and quite easily Apparently no one wondered why grafts broke There must be a reason What is it?

The author became interested in these problems in this manner In 1943 he began using very large massive grafts from the tibia, particularly in doing prop-graft fusions of the spine These grafts were cut out in rectangular pieces In 32 successive fusions in which large grafts were moved from the tibia spontaneous fatigue fractures occurred in 6 cases, and fractures due to excessive stress such as falls occurred in 2 other cases All of these occurred more than 6 weeks after operation, one as late as 7 months after operation (Figs. 1 and 2) All of these grafts were removed as rec tangular blocks cut from the tibia with a reciprocating motor saw This is no re-flection on the reciprocating saw Any circu-lar saw produces even worse defects, as will be shown by consideration of the principles advanced in this paper A study of this group of fatigue fractures revealed that all of them were propagated from one corner of the rectangular area from which the graft was removed and proceeded in an oblique direction across the bone (Fig. 3) Consideration of this fact led to the con-clusion that there was an excessive stress set up at this point, which was a transition

* Houston Texas.



Fig 1 Healing fatigue fracture at lower end of donor area.



Fig 2 Traumatic fracture through upper end of donor area.

point between intact bone and the bone from which the graft had been removed Then the shape of the graft area was altered so that both ends tapered to a point (Fig. 4) Following the adoption of this method and some further refinements applied at about the same time the author performed over 400 successive massive bone grafts using the tibia as a donor area Two fatigue fractures and 2 traumatic fractures occurred in spite of the fact that all these cases began unprotected weight-bearing less than 3 weeks after the removal of the graft.

The removal of the boat-shaped graft distributed the stress formerly applied at a single point over an area approximately 1 to 1½ inches in length. In discussing this problem with an engineer several other principles of structural strength were brought out, and the author learned of a book en-

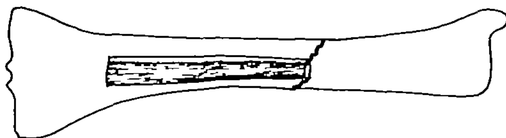


Fig. 3 Stress concentration at ends of donor area 7 fatigue fractures and 2 other fractures in 35 consecutive cases



FIG 4 Donor area shaped to distribute stress over a wide area

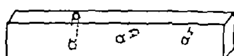




FIG 5 (*Top*) Stress concentration at vertical hole 3× hole at 45 angle 4× hole of any size transverse, 7× (*Bottom*) Expansion stress hole too small for screw cracks radiate out and cause subsequent fracture Draw screw has similar effect. Hole should be outside diameter of screw countersink shoulder of screw set screw snug but not tight

titled *Prevention of the Failure of Metals Under Repeated Stress* * This book is written as a guide in design and testing of various airplane parts and therefore is applied particularly to metals but many of the principles expounded are applicable to any structural material including bone Some of the principles covered in this book have very obvious and direct applications to bone surgery

There is a statement early in this book which should be quoted directly

Nature exacts the penalty when her laws are violated. Ignorance of the laws is no excuse to her Moreover to the family of a pilot who has been killed through the failure of a part which was obeying nature s laws, it is cold comfort to know that the slip made by the designer the machinist or the inspector was innocently made because no one sufficiently emphasized the natural laws that came into play

Likewise it must be small consolation to a patient to know that for the same reasons a bone graft has failed, or some reconstructive operative procedure entered into with high hopes for relief of pain and disability must be repeated or must be doomed to permanent failure.

When any structural unit fails, either under a single maximum stress or under repeated minimal stress there must be a point at which this failure starts Structural engineers call this point a fatigue nucleous." It may be a microscopic nick or crack or defect. It may be due to unintentional injury to the part during fabrication. The endurance strength of a substance is not altered by a nick or a crack, but the endurance strength of a given piece is altered vastly by it. The rear axle on a certain car model consistently broke at about 2 000 miles in all cars This was due to the part number which was stamped on the shaft. When it was put on the end of the shaft the breakage ceased.

The presence of a round hole in a part

* This is a handbook prepared for the Bureau of Aeronautics of the Navy Department by the Battelle Memorial Institute under the auspices of the National Research Council of the National Academy of Sciences, Wiley 1941

multiplies the stress by about 3 times (Fig. 5) A hole placed at a 45° angle multiplies it 4 times a transverse hole multiplies the stress 7 times A microscopic crack at the edge of the hole may reduce the resistance to zero The surface of a part is the most vulnerable area and the harder and more brittle substances are more affected by minute defects than are ductile substances As an illustration a 1/64 in deep notch in a steel bar 9 in. in diameter may reduce its resistance to stress by 50 per cent. Think of it Only 1/576 of the diameter of the piece has been removed but 50 per cent of its resistance to repeated stress is gone

The clamping stress applied by rivets and screws may reduce the stress resistance of a given part markedly How many times have you felt a sense of satisfaction as you set a screw down tight on a plate or a graft or an oblique fracture? Don t do it—you are weakening the part. Sharp corners are particularly prone to contain microscopic fatigue nuclei, and if a hole is bored the edges of the hole should be rounded and not left square. The throat of the screw is tapered. It cannot be flat if it is, the screw head may come off. Designers of screws know this but we have ignored its implications Expansion stresses produced by self threading screws greatly weaken the stress resistance of any part. The machinist carefully matches the hole to the threading tap (Fig. 6) Of particular importance is the proved fact that endurance strength can be increased in many cases by actually taking away material to remove a small notch

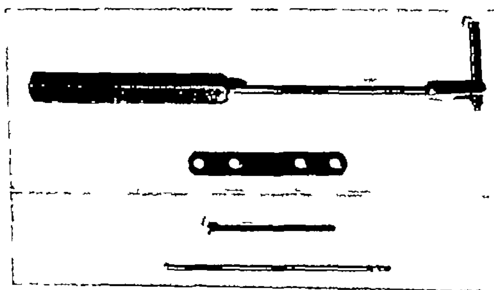


Fig. 6 (*Top*) Device for centering drill hole in plate. (*Bottom*) Drill properly sized for screw

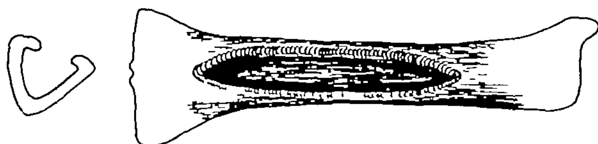


Fig. 7 Complete treatment of donor area. All corners and edges have been rounded off to remove all fatigue neuclei and to distribute stresses. There were only 2 fractures, and 3 fractures from falls in over 300 grafts.

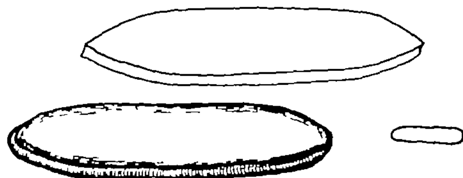


FIG. 8 (*Top*) Graft as removed. (*Bottom*) Graft ready for application. All corners have been removed to oval cross section Under surface has been planed off flat.

or crack and give wider distribution of stress Shatter cracks within a part also may serve as fatigue nuclei These statements constitute a summary of the more important applications of known principles of structural design Now let us apply some of these principles directly to bone surgery

Alteration of the shape of the donor area in the tibia to secure a wider distribution of stress has been mentioned (Fig 7) Further refinements consist of using a burr to round off all sharp edges and corners and remove all nicks until the edges of the donor area are completely smooth and the ends are not pointed but round. Every nick must be removed, even if this involves removing considerably more bone in order to get completely to the bottom of the nick this routine must be carried out with meticulous care in every case in which a bone graft of any size has been removed. In 1 case the integrity of one of the angles of the tibia was violated accidentally in removing a bone graft Using the burr the defect was removed completely This required the removal and the smoothing out of a defect so great that barely more than one half of the circumference of the tibia remained, yet this patient began walking some 10 days after operation and continued to walk to complete healing without the occurrence of a fatigue fracture Certainly any nick or angle or any concentration of stress in this area would have resulted in fracture. Fatigue fracture was anticipated it did not occur The stress was distributed widely The bone bent but did not break.

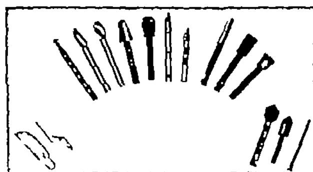


FIG 9 (*Left*) Saw blades to make curved cuts in bone (*Center*) Burrs and rotary files for removing defects and rounding corners Over 200 sizes and shapes. (*Right*) Countersinks to fit the hole to the throat of the screw

Having considered the donor site and its protection from overstress let us apply the same principles to the graft itself (Fig. 8) If we do we remove all of the sharp corners from the linear edges of the graft. There must be no nicks or defects however small, in those portions of the graft that will be subjected to stress, and it must be kept in mind that in bone these stresses will be tension, compression torsion and bending All alterations in shape and size of the graft must be made with precision cutting tools such as saws, drills and reamers, not with bone-cutting forceps and rongeurs, which have a shattering effect, radiating out from the cut A wide variety of tools for these purposes is available at any machine tool supply house (Fig 9)

Now we must fasten the graft into place bridging a defect (Fig 10) If we do this by means of a screw placed through the graft on either side of the fracture line, we have placed a round hole in it which may

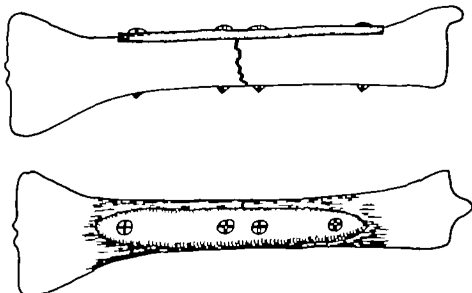


FIG 10 (*Top*) Flat surface prepared with rotary file, for receiving graft. This type of preparation prevents torsion and bending (*Bottom*) All screw holes of ample size and heads are countersunk Screws are tightened to graft contact and no more.

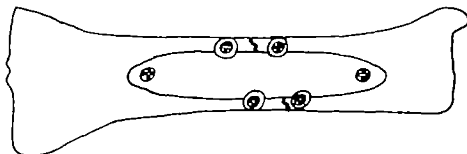


FIG 11 We may avoid the loss of strength due to drill holes near the fracture by this method Note that the fixation points are staggered

remove as little as one fifth of the actual width of the graft but certainly will cut its resistance to repeated stress to less than one half of that of the intact graft. Now if we force through this hole a self threading screw and subject the graft to an expansion stress producing microscopic cracks radiating out from the hole and then draw this screw down tight and with its throat cause further expansion cracks and compression stresses around the hole and further attendant cracks in the bone we may reduce the resistance strength of the graft almost to zero Some of these stresses apply if we use a draw screw principle to pull the graft down on the bone Any rough edge or ridge in the surface to which the graft is applied may cause concentration of the stress at this point and failure of the graft under repeated strain. Any curve in the site to which the graft is applied which causes bending stress on the graft when it is drawn down tight on the bone may increase the internal stress in the graft further and cause its failure Therefore if we are to conform to our principles the graft itself must not have any defects and the bed to which it is applied must conform exactly to the shape of the graft and must be absolutely smooth. If possible holes must not be drilled through the graft and particularly this must not be done near the site of the defect, at which the maximal stress will be applied to the graft.

It must be emphasized that any on-the spot testing gives no adequate idea whatever of the resistance to repeated application of stress that may be expected in any given mechanical setup

Suggested methods of holding the grafts in place are illustrated in Figure 11 If it is necessary to drill a hole through a graft the hole should be large enough to permit free passage of the screw or a bolt, and a nut should be used If it is absolutely necessary that the screw grip the graft itself, the hole should be tapped and reamed suitably before the screw is put in, or a washer

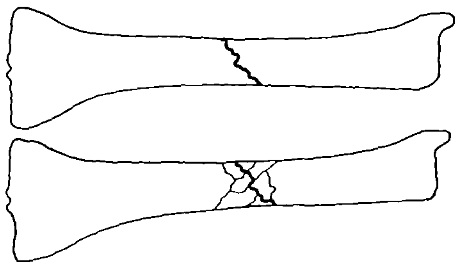


FIG 12. (*Top*) Appearance of crack by direct vision or under x rays. (*Bottom*) The actual condition is more like this. These accessory cracks may be invisible Later they break. Oblique screws usually fail for this reason.

should be used to distribute the stress around the screw head

These principles are of further importance in open reduction where every orthopaedic surgeon has noted that there are many fracture lines within the bone not visible in the roentgenogram which may appear when stress is applied in inserting screws and other internal fixation apparatus (Fig 12) After one becomes accustomed to thinking along this line violations of these principles will be apparent instantly There is no question that strict observance of them and further study of them will enable us to make a very significant improvement in the percentage of good results in a wide variety of reconstructive and reparative procedures

At times, reports have been made of the application of various testing devices used in engineering to the strength of various bones from the human body and to the strength of various internal fixation devices These findings give an indication of the physical properties of materials as obtained from static tests and usually are concerned with the elastic limits the yielding points and the ultimate strengths of various bones and orthopaedic appliances such as intra medullary pins and plates These are static tests and in no way do they reflect the conditions encountered in use Most of us at some time have applied a screw in an oblique fracture of the tibia and then picked up the leg and jerked it a few times in all directions to demonstrate the rigidity of the fixation What would happen if this jerk or stress were applied a thousand times or ten thousand times? Can any test that one may apply on the spot be used to give an indication of the resistance that a plate or a graft will afford to repeated bending and torsional stresses? Can any degree of solidity obtained in a spinal fusion at the time of operation give any indication of how these parts will stand up under repeated bending stresses in flexion and extension and lateral deviations of the trunk? They certainly cannot. Only planned attention to design at the time of fixation can allow a margin of safety to resist stresses to which a part will be subjected

We all know that if a piece of wire is bent once it will not break and that is what you are doing when you put a given amount of stress on a bone newly plated or grafted. But, we also are perfectly familiar with the fact that if you bend the wire 40 or 50 or 100 times it will break and this is exactly what happens in actual service in a bone. Stresses are being applied constantly even though the part may be in a cast. Thus, all the static tests of the breaking strength of bones and the bending strength of pins lose their significance what we want to know is not how much weight it takes or how much force is required to bend or break a part but how many times it can bend and how many times the force can be applied and not break the part.

Figure 13 shows the setup used to obtain

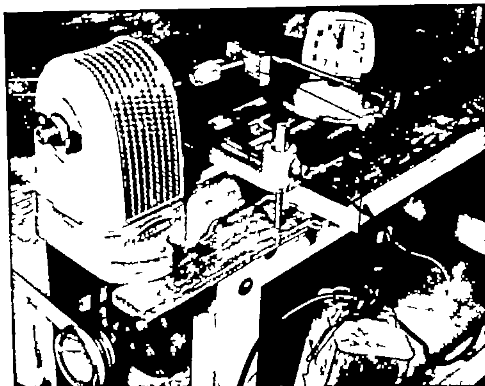


Fig 13 Lathe setup used for dynamic tests of effect of defects on resistance to repeated stress.

the statistics to be given in proof of the importance of these design factors and fabrication factors if we may use such a term, as applied to bone surgical procedures An ordinary wood lathe with a chuck is used to hold a piece of cortical bone of carefully measured length and diameter A small ball-bearing race is attached to the end of the piece of bone and to it is applied a sufficient amount of stress in the form of weight to produce a measurable lateral deviation Then the motor is started at a known number of revolutions per minute and when the bone breaks the motor and a timing device are shut off automatically By this means the effect on functional breaking strength imposed by various defects can be demonstrated.

The first fact determined was that there is a wide variation in bones Each set of tests had to be run on dowels made from the same bone (Fig 14) Large heavy bones

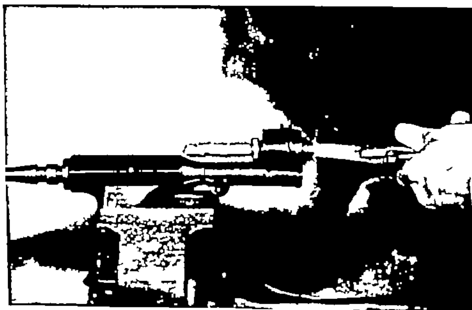


Fig. 14 Method of cutting test dowels

are very brittle smaller bones are more resilient and less sensitive to minor defects The first pieces used broke at once After considerable trouble, this was determined to be due to hitting the end of the dowel with a hammer to drive the bearing on the end A control average of 48 minutes was established A set in which the end of the dowel was struck 10 light blows with a hammer ran a variable time from 1 to 30 seconds

Accidental defects such as a flat side on a dowel or a nick from gripping the dowel with pliers resulted in a running time of about 3 to 8 minutes The smallest holes caused almost immediate breakage. Ring burns on the dowel produced by the cutter so weakened the bone and concentrated the stress that they caused instant breakage All tests were run on groups of 5 pieces as nearly alike as possible and made from a single bone The control average was made from 10 pieces The smallest discernible saw-cut caused almost instant breakage.

CONCLUSION

These are some of the reasons why our well-laid plans fail The ideas presented here only scratch the surface and much remains to be done about the application of these principles to specific problems It is hoped that the reader has been stimulated to begin thinking seriously about this aspect of orthopaedic surgery There are bits of useful knowledge in many other fields that could be applied at once in ours Thus engineering knowledge has been ignored, in a large part, too long

9

Antibiotics and Chemotherapy

Will the Widespread Use of These Agents Upset Our Present Knowledge of Bacteriology?

A Review of the Drugs, Their Actions and Reactions

FRANCIS W GLENN, M.D *

The subject of antibiotics and chemotherapy by an orthopaedic surgeon may seem to be a little out of routine. The author's interest in searching the literature both clinical and research, became more and more intensive as he was confronted with many unknown and unexplained problems for which he could not find a logical answer He started this study on antibiotics and chemotherapy in the various stages of osteomyelitis but then felt that a general review of this timely subject might be more valuable

We have been bombarded with the "rosy side" of the picture by the drug manufacturers and their detail men, and often the other side of the picture has been soft pedaled Since so many new drugs are coming out which are said to be effective against organisms that are resistant to the other antibiotics it is no wonder that we become confused. The recent trend, according to reports seems to show that organisms are becoming resistant to the newer drugs much faster than they did to penicillin. It is unfortunate that the lay press has publicized these "wonder drugs" so widely and again they tell only one side of the story Probably all of us have had the experience many times when patients come into our offices asking for a shot of penicillin for a cold or other minor ailments Many others with whom this matter has been discussed say that they have had numerous similar experiences When questioned, many of them stated they went ahead and gave it since the patient undoubtedly would go to another doctor who would give it to him. Their ignorance of the possible dangers of loosely administering these drugs is the same as the author's prior to the investigation of this tremendous subject over the period of the last 5 years.

In acute osteomyelitis there is very little difficulty in antibiotic management, especially if the organism is known prior to beginning antibiotic therapy The vascularity of the tissues involved is plentiful in that stage and the blood stream can carry the drug to the desired site However in the chronic cases the blood supply is at a premium especially in those who have had the disease for many years.

The author has had considerable experience with organisms becoming resistant to many of the antibiotics. In one case R. W male aged 52 had osteomyelitis involving both upper and lower extremities and the ilium on the right side for 38 years before the author first saw him. His organisms have become resistant to all of the available antibiotics. The author is hopeful that the time the patient has a flare-up and

*Miami, Florida.

tainly will his organisms again may become susceptible to penicillin This assumption is based on the experiments of Monnier and Schoenbach, which will be referred to later in this paper (pp 109 110)

The next plan of attack in these chronic cases is to get a culture of the pus and have a specific autogenous vaccine prepared. Of course sensitivity tests are done to all the available antibiotics at that time and the drugs are kept in reserve and in some cases the culture is refrigerated for future reference The author feels that this plan in the chronic cases especially with multiple involvement, should be routine The methods of preparing *specific autogenous vaccines* have been so simplified that it is now possible to prepare one in a short time When it is used, we should not give antibiotics at the same time

The author is indebted to clinical and research bacteriologists because of their tremendous help in reviewing the notes and in smoothing out the section relating to the physiology the pathology and the biochemistry of the various organisms Their studies have received tremendous impetus within the past 15 years Interestingly enough, they are using antibiotics in their experimental work in genetics metabolism and biochemistry of the various organisms and in doing biologic assays

Bacteriology is a tremendously expanded profession and will continue to become more complicated since the advent of antibiotics and chemotherapy

Since most of the articles in our clinical journals deal with some specific organism or some specific drug in one or more diseases, it might be worth while to try to present as broad a picture as possible of the drugs themselves and very briefly of the allergic type reactions of various kinds and the anaphylactic reactions of mild to severe types. Also a brief comment will be made on the most widely accepted theories on how these drugs kill the bacteria, and also on theories concerning the development of resistance

Each of us in our various fields as medical practitioners clinical and research bacteriologists physiologists biochemists drug manufacturers etc is so occupied in various endeavors that the "whole picture" of what effect the world wide impact of antibiotics and chemotherapy will have on our coming generation may escape us Therefore a review of this type, covering many of these factors is submitted with the hope that this effort will be worth while

Now we can use with certainty the term "cure" for such one time scourges as syphilis gonorrhea and subacute bacterial endocarditis and these diseases have become less threatening in the acute stages Near miraculous cures are reported of many infectious diseases. Mortality and morbidity rates of childhood diseases surgical operations and infirmities of old age have been improved by these blessed agents However there is a price that must be paid in many instances in order to reap these benefits The two most common dangers are antibiotic resistance of organisms and early or late sensitivity reactions of various types in our patients We are all aware of the fact that these agents have been used for everything from "dandruff to plantar warts" Such indiscriminate use is to be condemned The author knows of no statistics on the percentage of the general population on a national scale who have received one or more of the chemotherapeutic or the antibiotic drugs at some time in their lives. Probably more people have received penicillin than even the sulfa drugs, since the latter were put in the background to a large degree when penicillin became available on the market. Now with the new broad-spectrum antibiotics our unknown problems are multiplied Therefore it is obligatory to ask our patients, or the family in the case of infants and children, whether or not previous sulfa drugs or antibiotics have been given, for what diseases, approximately how much and how long ago We also should inquire as to any suspected or real sensitivity reactions

AN ANALOGY IN THE INSECT WORLD

The experiences of entomologists all over the world should warn us of the multiplicity of problems which face us. C E. Palm [1] in his presidential address (1953) appealed to all entomologists in the United States to co-operate fully with allied professions here and in other parts of the world who are dealing in public health and he cited the responsibility of the entomologist in his dedication to human welfare This includes the entire medical profession in all of its many branches and especially the public health services He made a plea for extensive study and basic research in the physiology the biochemistry and the genetics of the various species of pests affecting human beings and the food and the fiber that they need He stated that "the fascinating studies of the physiologist on the effect of hormones and enzymes on the metamorphosis, metabolism growth and reproduction in insects are as intriguing as they are important." He sounded a solemn warning in regard to resistant organisms as a result of the extensive use of chemical insecticides. He urged a return to fundamentals in the control of reproduction.

The Florida Entomological Society (May 1954) urged the mosquito control board to intensify previous methods of drainage and filling of breeding places as an absolute necessity in the control of mosquitoes in that state.[2] The mosquitoes have become increasingly resistant to all the known chemical insecticides and combination of insecticides, and DDT is considered as practically useless at this time Generally the insecticides fall into two large groups of chemicals

1 The chlorinated hydrocarbons which include DDT lindane chlorodane methoxychlor TDE, BHC, aldrin, dieldrin, endrin, hepatachlor and malathion. Because of their similarity in chemical structure their efficacy is short-lived once they have become resistant to one of the group

2 The organic phosphate group of which parathion is an example has been found to be especially effective against organisms resistant to the above group However resistant strains to parathion already are appearing Those critters" which were not killed by the first the second and the third onslaughts of chemicals survive and reproduce in tremendous numbers and are not influenced by any available chemical For this reason the basic principle of eliminating breeding places appears to be the last resort at the present time

Biologic control of insects has been used for many centuries The first written record on the transportation of beneficial insects by man was made by Forskal in 1775 He reported that the date palms in Arabia were attacked by ants which often destroved not only the fruit but also the trees themselves The growers introduced colonies of "predatory" ants annually from the mountains and these controlled the "pest" species The use of predatory ants for the protection of orchards against insect pests is a practice of long standing in various Asiatic countries and still is employed Many examples of the biologic control of insects and transportation of insects from one region to another were reported by Sweetman in 1936 [39] An outstanding example was a ladybug beetle *(Vedalia cardinalis)* imported from Australia into California in 1899 to control the cottony-cushion scale Predatory insects or parasites were used to combat the oriental fruit moth in the peach industry in New Jersey from 1938 to 1947 [8] In 1947 1952 the parasites were used, together with a minimum of chemical spraying and this combination is economically sound and much better than chemicals alone When chemicals are used too early often the "beneficial" insects are destroyed, and pollination is interfered with To recall a few of the tremendous contributions of the entomologist, we must consider the control of such diseases as malaria yellow fever bubonic plague epidemic typhus and other scourges of mankind that are spread by mosquitoes flies lice ticks and fleas The majority of this work was done prior to the chemical era

In our own profession a few examples which can be considered biologic control, even though somewhat indirect, are vaccination for smallpox, inoculations for diphtheria and typhoid fever and many other vaccines sera etc A more recent example is the ingestion of cultures of normal feces by persons with intense diarrhea following the use of broad spectrum antiseptics [4] together with large doses of vitamin B complex, milk buttermilk yogurt etc., in an *attempt to re-establish the normal bacterial* population (flora) [4a]

A review of the development of some of the most important agents may help us to have a better understanding of their actions and reactions It is not possible within the scope of this paper to give all the theories on their mode of action toxicity development of resistance and combined antibiotic therapy with its myriad ramifications I shall discuss briefly the drugs in most common usage and give the most widely accepted theories with references to source of material.

THE SULFONAMIDES

As we all know chemotherapeutic agents for systematic use in the human are not new Salvarsan was developed by Ehrlich before World War I Sulfanilamide first was synthesized in 1908 by Gelmo a German organic chemist and was used in the dye industry In 1919 Heidleberger and Jacobs observed that sulfanilamide coupled with hydrocupreine, was bactericidal in vitro [5] In 1935 Domagk using the same combination announced that it was bactericidal in vivo as well. He called it prontosil In the mean time French investigators under the direction of Fourneau et al postulated that rubiazol (their name for the same substance) was reduced in human body to form free sulfanilamide and demonstrated that the *latter compound expressed antibacterial ac*tivity This amazing discovery opened the way for extensive experimental and clinical studies since the universal use of the sulfonamides was not shackled by patent rights. *Neoprontosil a less toxic substance* came immediately afterward.

Extensive clinical work began soon afterward in this country using the two drugs, neoprontosil and sulfanilamide There was much confusion at first. Neoprontosil seemed to turn the patients pink and sulfanilamide turned them blue Realizing the very toxic properties of these drugs thousands of new compounds were developed but only a few were found to be useful and reasonably *safe Of these,* some of the most useful are sulfadiazine sulfamerazine sulfamethazine, sulfapyrazine the triple sulfa compounds, gantrisin and more recently elkosin and thiosulfil. (Sulfathiazole was removed from *New and Nonofficial Remedies* by the Council on Pharmacy and Chemistry of the A M A first as an individual drug and later as a component in mixtures [6 36 37])

The sulfonamides have approximately the same degree of effectiveness However there are differences of solubility absorption penetration metabolism and rate of excretion. These drugs are sparingly soluble in water The solubility increases as the pH and the temperature of the medium are raised.

All of these sulfonamides have a tendency to crystallize in the kidneys—some more than others—and a careful check on the urine should be made in all cases receiving sulfonamide therapy They should maintain at least a 1,500 to 2 000 cc. daily output for an adult and should receive alkalinizing therapy whenever the urine falls below pH 5 5 Keeping the urine pH above 6.5 to 7 increases very markedly the solubility of the sulfonamides

For the past few years, combined sulfonamide mixtures have received widespread use in order to achieve further reduction of crystallization of the drug in the kidneys. The solubility of each of the sulfonamides *is independent of the presence of others,* and the use of the mixtures gives a therapeutic effect while reducing very markedly the possibility of crystallization.[6a] One combination, namely 0 167 Gm. each of sulfadia-

zine sulfamerazine and sulfamethazine, has the same therapeutic effect as 0 5 Gm of any one of the three but the amount to be excreted is equivalent to only 0 167 Gm of each drug When using these drugs it is necessary to establish a high concentration in the body and the initial dose should be large as will be explained later in this paper The initial dose should be 4 to 6 Gm in adults and ½ of the calculated 24-hour dose in children. Doses of 1 Gm. or more should be given thereafter every 4 hours around the clock in adults, and corresponding doses in children. As the patient improves the dose and the frequency may be decreased as his condition permits

Blood level tests are not as reliable as once was thought, since little is known how much is present in the various tissues at any given time The clinical course of the patient is the most important check. If there is no improvement within 48 to 72 hours, then a re-evaluation of the case should be made

Gantrisin, elkosin and thiosulfil are some of the newer and more highly soluble sulfonamides Their advocates claim that they do not precipitate in the kidneys and need no alkalinization and are active against a wide variety of organisms The last two have been used clinically in this country for only a little more than 2 years. These and similar sulfonamides now being developed may displace the previous ones exactly as the latter displaced others before them.

The sulfonamides do not show their effect for from 4 to 7 hours and only act when bacteria are multiplying

The toxic reactions of the sulfa group are well known. They include nausea, vomiting, headache general malaise mental depression, drug fever various skin rashes, agranulocytosis hemolytic anemia and leukopenia

PENICILLIN

Penicillin was discovered by Fleming in 1929 Chain and Flory in 1940 reported its effectiveness against pathogenic organisms In the past 14 years numerous antibiotics have been discovered. Penicillin is probably the most widely known of the so-called "miracle drugs." Numerous types of penicillins have been prepared some of which are Penicillin G X, F K and, more recently, Penicillin O Penicillin G is used most widely because it is produced on a large scale more easily For this reason, practically all of the penicillin now available on the market is Penicillin G The penicillins are freely soluble in water but they are unstable in its presence and therefore if aqueous solutions are used, they should be made fresh and refrigerated for no more than a few days for maximum efficiency Procaine base combined with Penicillin G forms a compound which is almost insoluble in either water or oil Therefore procaine penicillin can be prepared as a suspension suitable for intramuscular injections. Thus a depot is established from which absorption is prolonged. Specially buffered aqueous suspensions of procaine penicillin retain their stability for months if refrigerated Penicillin G is available for intramuscular oral or topical administration. A dosage by any route depends on the severity of the infection. In using aqueous penicillin, divided doses should be given at intervals of from 3 to 6 hours If oral penicillin is used the dosage should be from 3 to 5 times the estimated dose of that by intra muscular injection.

Reactions due to allergic hypersensitivity are reported in about 5 per cent of the cases who never had it before some of these can be controlled by antihistaminics and if not, the drug should be stopped. Many patients have become sensitized to penicillin and, even if not sensitive at first, on a second or a later course they may show a mild to a very severe allergic reaction Many cases of various types of allergies and anaphylaxis have been reported. Mayer et al. (1953) reported severe anaphylactic reactions to penicillin in 6 cases which required dramatic treatment.[7] One patient, a 47-year-old white man, started treatment in 1943 for an inadequately treated lues During

years he had received 3 courses of penicillin, consisting of 2½ million 5 million and 7 million units respectively with no ill effects In November 1951 he developed an upper respiratory tract infection and he bought some penicillin troches "over the counter" He took one troche and fainted almost immediately but recovered spontaneously He returned to the hospital in January, 1952 Because of the persistent positive serologic tests he was started on another course of penicillin and was given 300 000 units of aqueous procaine penicillin intramuscularly Immediately after injection he complained of a peculiar feeling in his chest, similar to that which he had when he took the penicillin troche two months before and almost immediately collapsed into coma Blood pressure and pulse were not obtainable He died within a few minutes Mayer et al. stated that Waldbott, in 1949 reported the first death due to penicillin anaphylaxis Others have been reported since They stress the importance of skin testing in all patients who have received previous treatment with penicillin, especially if they have had any untoward reactions

Recently Penicillin O* has been produced in limited quantities and many of the patients sensitive to Penicillin G can tolerate Penicillin O Furthermore Penicillin O is recommended for use against Penicillin G resistant organisms However this work is very new and judicious application rather than enthusiastic acceptance should be the order of the day since bacteria are famous for their ability to develop resistance to new antibiotics

STREPTOMYCIN AND DIHYDROSTREPTOMYCIN

Streptomycin and dihydrostreptomycin may be used as an adjunct in the treatment of bone infections along with penicillin, and several products are put out combining the two in the same ampule It is thought that the use of streptomycin would prevent the gram negative organisms from predominating after penicillin had destroyed the gram-positive organisms in a mixed infection Streptomycin and dihydrostreptomycin are used very effectively in the treatment of tuberculosis and when combined with para-aminosalicylic acid, the development of resistance is said to be markedly delayed. Streptomycin is said to be more toxic to the eighth nerve and the vestibular apparatus than dihydrostreptomycin. Recent reports indicate that it is not necessary to give more than 0 5 Gm twice a day of dihydrostreptomycin with 8 0 to 16 0 Gm of para aminosalicylic acid daily in divided doses the dosage level and the frequency are lowered for optimum results, making it possible to use them over a longer period of time. Recent reports in cases of tuberculosis indicate that after the initial improvement, this combination can be given every other day and then decreased gradually to twice a week over a long period of time This synergism of action between an antibiotic and a chemical compound reveals a new thought, namely that further studies in using chemical compounds with antibiotics in gram-positive pyogenic infections may be of help to us in the treatment of bone joint and other infections

Broad-spectrum antibiotics are relatively new therapeutic tools and are not as yet time tested They are active against a wider variety of organisms than heretofore seen in any one of the previous drugs They are especially useful against penicillin- and sulfa resistant organisms Resistance to them is being reported more frequently recently

CHLORTETRACYCLINE

The first report of the discovery and the properties of chlortetracycline (Aureomycin) was made by Duggar in 1948 [8] It is active in vitro and in vivo against a wide variety of both gram-positive and gram-negative organisms On a weight basis, chlortetracycline as well as the others of this group is considerably less active than penicillin against most gram-positive organ-

*Depo-Cer-O-Cillin (Upjohn)

isms It is especially effective against sulfonamide and penicillin resistant staphylococci and streptococci Chlortetracycline is not given intramuscularly routinely because of its irritative qualities

Average adults require 500 mg. intravenously every 12 hours. This dosage may be adjusted upward to as much as 500 mg every 6 hours, never more or downward according to the severity of the infection Intravenous therapy should be employed only in hospitalized patients who are unable to take medication by mouth it should be replaced by oral therapy as soon as possible. The use of vitamin B complex in full dosage also milk, buttermilk, yogurt or acidophilus milk, is considered helpful in preventing too much upset in the normal bacterial flora in the gastro-intestinal tract and always should be given to any patient requiring broad spectrum drugs for a period longer than 5 to 7 consecutive days.

OXYTETRACYCLINE

Oxytetracycline (Terramycin) came later and is a broad-spectrum antibiotic Oxytetracycline and its hydrochloride show no detectable loss of potency on prolonged storage at room temperature It is active both in vitro and in vivo against a wide variety of both gram positive and gram-negative bacteria. The initial dose of oxytetracycline recommended is from 1 0 to 2 0 Gm. followed by 0.5 Gm by mouth every 6 hours and later by 0 25 Gm Oxytetracycline is dispensed in either capsules or coated tablets and is available for intravenous and intramuscular use as well

ERYTHROMYCIN

Erythromycin is a newer broad-spectrum antibiotic very similar to that of chlortetracycline and oxytetracycline Its indications and dosages are approximately the same Recently it has been used effectively against staphylococci resistant to chlortetracycline and oxytetracycline [10]

CHLORAMPHENICOL

Chloramphenicol (Chloromycetin) is a broad-spectrum antibiotic which, when used with proper precaution, is an excellent drug There have been numerous reports of aplastic anemia reported from its use [11 12 13 14] It is believed that if the dosage is kept to a minimum and not given over a long period of time, chloramphenicol still will remain a very useful drug

TETRACYCLINE HCl

Tetracycline HCl (Achromycin) is one of the newer and still relatively untested antibiotics and fits within the same group of drugs as chlortetracycline and oxytetracycline. It is said to be the active factor in both the latter antibiotics It is reported to act against strains resistant to the others in this class

BACITRACIN AND TYROTHRICIN

Bacitracin and tyrothricin are excellent for topical application and may be used in conjunction with other antibiotics in an attempt to eliminate contaminating organisms, as well as those not susceptible to the drug simultaneously given by way of the blood stream.

PROBLEMS

Broad-spectrum antibiotics have brought numerous problems to both the clinician and the bacteriologist The alteration of the normal bacterial population in the mouth and the entire gastro-intestinal tract has led to many serious complications Various types of yeast have been permitted to predominate when their natural enemies have been eliminated or reduced in number Severe and sometimes rapidly fatal staphylococcic diarrheas have been reported very frequently and a few are cited in the following paragraphs

Finland, in 1951 had several patients under treatment with broad-spectrum antibiotics who developed severe diarrhea the stools showed pus and blood, and the culture of these stools yielded coagulase positive hemolytic *Staphylococcus aureus* as the predominant organism and occasionally, as the only organism which could be cultivated on blood agar plates [15] This organism was resistant to chlortetracycline and oxytetracycline

Jackson et al. stated that these staphylococcic infections in seriously ill patients resulted in a deterioration of their condition *at a time when their primary infection* (which was pneumonia in their cases) was being eliminated.[16] "This form of dysentery prolonged the period of morbidity of many of the patients who recovered and played an important role in the failure of some of the patients to survive "

In the opinion of Dearing and Heilman, smears and cultures of the throat and stool should be made in all suspected cases, and if staphylococci are found in sufficient numbers, chlortetracycline and oxytetracycline should not be given. If the smears made after the onset of the disease reveal large numbers of staphylococci and the patient is gravely ill, erythromycin should be started immediately[10] In the cases where erythromycin was used it was found to bring the staphylococcic enteritis under prompt control. There were 44 cases in their series all but 4 of whom had previously received broad-spectrum antibiotics with 2 deaths They stated that 'broad spectrum antibiotics should not be used in minor infections "

Hay and McKenzie, in Great Britain reported a number of cases of severe "staphylococcic" diarrhea, which was rapid in onset and fatal within 18 to 24 hours[17] They likened the severe cases to Asiatic cholera and remarked that "Jonbon, et al. (1952) called this syndrome 'le syndrome choleriforme de la terramycine " In 1 case of death no attempt was made to culture the staphylococcus, as they did not suspect it at the time In another case a pure culture of staphylococcus was found at autopsy in the stool the mouth from all sections of the intestinal tract and the lungs which was resistant to penicillin chlortetracycline and oxytetracycline and sensitive to streptomycin and chloramphenicol They reported another case of very severe diarrhea with marked dehydration in a 2 year-old child who had pure cultures of streptococci from the mouth which were resistant to penicillin chlortetracycline and oxytetracycline and sensitive to chloromycetin and streptomycin. Intravenous fluids and intravenous sulfadiazine, 1 Gm every 4 hours, and intramuscular streptococcic serum 10 000 units, were given and a prompt recovery was effected. They postulated that broad-spectrum antibiotics upset the "host parasite-drug" complex, of which we know very little. They urge that broad-spectrum antibiotics never should be used in minor diseases, as did Dearing and Heilman earlier

Hofer and McCaskey divide the many mechanisms that may play a part in antibiotic resistant superinfections into 3 groups

1 Environmental (antibiotic suppression of sensitive organisms upsets the symbiotic state)

2. Possible stimulation of bacterial growth by the antibiotic.

3 Tissue alterations may include vitamin deficiency provoked by aureomycin, terramycin and chloromycetin The alteration in the intestinal flora may favor acute enterocolitis as a result of local tissue alteration perhaps associated with decreased body resistance.[18]

An increasing number of reports on similar complications are being made all over the world One interesting fact in these reports is that the dysenteric stools were purulent and bloody in only a few cases, while the majority of cases reported here and in England were described as a copious, greenish diarrhea. Ordinary stool cultures were negative but blood agar and other media revealed the staphylococci often in pure cultures.

THE MODE OF ACTION OF THESE DRUGS AND THE DEVELOPMENT OF RESISTANCE BY BACTERIA TO THEM

Ehrlich the pioneer investigator in chemotherapy postulated that chemical antimicrobial agents exert their effect by combining with specific chemically reactive groups of the susceptible bacterial cell He called them "receptors " He further indicated that these chemical structures in the microbial cell had specific attractions or affinities for only certain other chemical compounds. *In other* words, these "receptors" combine with spe

cific food components so essential to proper metabolic function of the microbe His basic idea was that in nature there exists chemical compounds similar in structure to these specific food components needed by the microbial cell and that the cell s "receptors" combine with these drugs almost as readily as with the food components. The cell is being "hoodwinked into "coupling on" the drugs rather than the food Once the drug is combined with the microbial cell, it is now toxic to that cell in the sense that it blocks a vital metabolic pathway for the organism Because of their specific affinity or attraction for certain drugs only these "receptors" even were given names for a time, such as arseno receptors acetico receptors orthoaminophenol receptors etc

The years moved along, and the biochemist and the bacterial physiologist could do little to verify Ehrlich s views. Their knowledge of the biochemical processes involved in cellular metabolism and structure was too limited to advance this original concept. In fact, soon after Ehrlich, the findings appeared to be incompatible with his views concerning specific receptors It was shown that bacterial killing agents were toxic not only to bacteria but also to host cells as well. The iodides, the chlorides and the peroxides had oxidative action on all protoplasm the heavy metals phenols, etc denatured all protein and the detergents and surface acting agents disintegrated structural complexes on all organisms Therefore, antiseptic action seemed to be in no way linked with specific chemical receptors on microbial surfaces

However recently laboratory workers have become interested in the chemical reactions between inhibitors and microbial cell constituents The newer viewpoint is a sort of revival of the receptor theory but is based on the recently acquired knowledge concerning the chemical structure of the microbial cell the biochemical reactions and the enzymes involved in the processes of nutrition respiration and growth. It is this last aspect of the problem, the effect of antibacterial agents on metabolic processes, which is most acceptable today

Fildes (1940) expresses it in this way

> The growth inhibiting effect of antiseptics in general might be due to a specific poisoning of some essential reaction exerted through an interference with the catalyst or essential metabolite

A complete survey of the killing action of antimicrobial agents should include then the specific chemical agents which can block or interfere with essential metabolic reactions the enzymic and chemical reagents which can selectively alter or destroy the organism s structure (detergents etc) and those agents which nonspecifically affect the protoplasmic constituents of all living cells

What, then, is the mode of action of the sulfonamides? We have mentioned the "receptor theory" and designated that receptors on the bacterial cells can be tricked into accepting "fake" molecules which they can not use An enzyme essential to the organism is deprived of nutriment, and a vital element goes dead. Either the patient s cells do not need the enzyme that the organism must have or they make more than enough of the enzyme Therefore the patient s cells are uninjured by a drug molecule that is deadly to the organism

In the case of the sulfa drugs there were many hints that this was probably the case Sulfas did not kill instantly even in the test tube The growth rate of the organisms was slowed down greatly and apparently in some subtle way the bacteria were starved to death The drugs have little or no effect on bacteria that are not actively multiplying In 1940 D D Woods advanced an explanation of the action of sulfanilamide on bacterial cells which now is accepted fairly generally [16] The chemical structure of the sulfanilamide molecule with the exception of one radical, is identical with that of para aminobenzoic acid—PABA for short—a part of the vitamin B complex. Sulfanilamide then, is a chemical analogue of PABA. Many bacterial cells need PABA for their existence exactly as all *higher* organisms

need their essential vitamins When sulfa combines with the receptor on the bacterial cell intended for PABA it inhibits this vitamin from combining onto the same receptor The organism is starved for that particular vitamin, and its end is near Thus a "fake" molecule competes with PABA for space on the surface of an enzyme system essential to bacterial life This is called "competitive inhibition"

Woods further stated that 'the bacteriostatic action of 1 000 molecules of sulfanilamide is inhibited by 1 molecule of PABA The latter occurs free in human plasma in very low concentration and in somewhat higher concentration in a bound form which can be liberated by acid hydrolysis Other substances containing the aminobenzoic group exert an effect similar to that of the PABA acid, such as peptone certain amino acids procaine and many others

Urea appears to increase the bacteriostatic action of sulfonamides in vitro and in vivo when applied locally to wounds. Therefore these factors have been largely responsible for the wide variation of in-vitro tests for sensitivity of specific organisms to the various sulfonamides in different laboratories

Other factors include the species and the strain of the test organism, the composition and the pH of the medium the age and the size of the inoculum, the medium, the diluting fluid the concentration and the stability of the drugs used, the temperature and the duration of incubation and finally the criteria used to determine activity White noted that "when concentrations of sulfonamide of *less than 1 000 mg. per 100 cc* were used against streptococci it produced a difference in inhibition of 100 to 1 when the temperature was raised from 30 C. to 39 C"[20]

In the light of this theory how does penicillin effect its killing action on microbial cells? In the first place the penicillin molecule is a much more complex one than the simple sulfanilamide molecule Yet the evidence indicates that both drugs affect susceptible organisms in much the same way For all practical purposes both can be considered as antimetabolites or substitution agents, that is latching onto a bacterial cell and blocking a metabolic pathway essential to the life of that cell.[21]

The penicillin *molecule is extremely similar* in chemical structure to a molecule of glutathione This latter substance a tripeptide contains amino acids that are essential to the detoxication processes of the bacterial cell Then a bacterial cell which may require some fraction of the glutathione molecule e g. glutamic acid absorbs a very similar penicillin molecule instead, and thereby a vital metabolic pathway is blocked and starvation sets in Another view is that penicillin might combine with glutamic acid and prevent absorption of this amino acid by the microbe Still another proposal is that penicillin inhibits ribonucleic acid necessary to the life of the bacterial cell and yet has no similar effect on the animal cell. The important point is that antibiotics function as biologic antagonists or antimetabolites[22] and this very phenomenon is opening vast and wonderful horizons in modern drug research.

Streptomycin, it appears blocks the passage of certain carbohydrate intermediates into the Kreb s cycle that is, the terminal respiration system of the cell It inhibits oxidation of pyruvate and oxalacetate steps necessary for the basic energy change of the individual cell[23] The details of this inhibition are not understood at present. Since the metabolic step which streptomycin apparently affects is of extreme importance to all animal tissues why does not *streptomycin cause great harm to the host?* In essence the answer lies in the fact that streptomycin ordinarily does not reach the mitochondria (granular or rod shaped particles in the cytoplasm) where these reactions occur yet it does reach the sensitive areas of certain micro-organisms When resistance to streptomycin develops (as in the "by pass" action of penicillin resistance) it is because the particular strain of organism has been able to get along without the

"oxalacetate pyruvate reaction" and presumably has a new path for these metabolites

Little is known of the action of chlortetracycline and oxytetracycline Wong, Barban and Ajl believe that they may not act on any one step but rather on the phosphorylating mechanism[24] They apparently inhibit the incorporation of phosphorous into the nucleic acid fractions and into organic phosphate

Chloramphenicol may have at least 2 sites of action. Because its structure rather closely resembles that of the amino acid phenylalanine[22] it may act as an antimetabolite and render certain enzymes inactive by displacing phenylalanine Furthermore in *Escherichia coli* the antibiotic apparently inhibits the formation of an enzyme gluconkinase which converts gluconate to 6-phosphogluconate[25]

In attempting to understand the manner in which bacterial organisms can develop resistance to certain drugs one must accept the fact that micro-organisms possess nuclei exactly like those of higher organisms The bacterial nucleus problem has been a controversial one for more than a half century but the more recent work of such men as Robinow Tatem, Beadle Hederburg, Demarec DeLameter[21] and others leaves little ground for further question on the existence of a bacterial nucleus Therefore the bacterial cell goes through the processes of mitosis and miosis in other words division and reduction, whereby the chromosomes align themselves and split evenly to form two daughter cells The chromosomes carry the genes and a theory that is now popular is that one gene is responsible for one enzyme system—the "one gene-one enzyme theory" In very rare instances 1 case out of 1 billion an unequal distribution of genes occurs, leaving a new cell lacking in a specific enzyme Should this enzyme be the one needed for PABA synthesis the sulfa drugs could have no effect on this organism since it could not block a nonexistent enzyme thus a sulfa-resistant cell is born

Another view states that since genetics are at play among bacteria too a microbe can be produced in a colony that has an oddity of metabolism and can thereby "short-cut" or "by-pass" a block caused by an antibiotic in one of its metabolic pathways Still another theory is that some bacteria become adapted to certain drugs or that altered hereditary traits may arise by mutation.

The antibiotics vary greatly in their ability to induce resistant strains among the bacteria It is evident now that all species of bacteria can become quickly resistant to streptomycin and, surprisingly enough some bacteria now even require this antibiotic as an essential food Unfortunately the newer antibiotics are encountering increased numbers of resistant strains or variants Penicillin has received some harsh criticism since more and more staphylococcic infections failed to respond to it. The drug seemed to be losing its effectiveness against this genus of organism. However from examination of the record it now is suggested that in the early days of penicillin therapy the resistant staphylococcic strains were not particularly widespread and penicillin was effective against the general run of staphylococcic infections Then gradually the penicillin-susceptible strains were diminished slowly by widespread use of the drug and the resistant strains became more and more common[21]

Monnier and Schoenbach,[26] in 1951 testing the sensitivity of organisms to the various drugs after exposure to others noted

"An increase in susceptibility to penicillin was repeatedly observed in microorganisms which had been exposed to aureomycin, chloramphenicol, terramycin or streptomycin. The degree was more marked when strains originally shown to produce penicillinase were studied. This augmented sensitivity appeared to be related either to a decrease in the production of or an inhibition of the enzymatic activity of penicillinase Only a slight loss of this increased sensitivity was observed after subsequent transfers in broth without the antibiotic. Penicillinase production by these strains of microorganisms did not return after these latter transfers, and it is interesting to speculate as to the possible cause for the maintained inability of the

strains to form penicillinase The relationship of resistance to penicillin unaccompanied by the production of penicillinase is also of great interest as to the mechanism concerned Spink has reported that staphylococci made resistant to penicillin did not acquire the ability to form penicillinase He also found that such induced resistance was only temporary The strains of staphylococci which were found to possess a "permanent" type of penicillin resistance formed penicillinase He indicated that the production of penicillinase was characteristic of such organisms which could arise by mutation. Luria did not believe that penicillinase production was directly related to the development of resistance to penicillin."[20]

They further stated

"With the exception of loss in the ability to produce penicillinase, which was associated with an increased susceptibility to the action of penicillin—a finding which was noted when certain strains of microorganisms were exposed to aureomycin, chloramphenicol, terramycin, or streptomycin—the changes in sensitivity to penicillin were independent of the acquisition of resistance to the other antibiotics. Streptomycin and polymixin B also appeared to act as separate and independent entities Aureomycin chloramphenicol, and terramycin appeared to be closely related in that when resistance to one of these antibiotics developed the same was true with the others in this group although chloramphenicol differed somewhat in respect to the gram positive cocci."

It would appear hopeful then that many of the "newer generations" of bacteria again may become sensitive to penicillin. It would appear from the conclusions of Monnier and Schoenbach that streptococci do not become resistant to penicillin as quickly as do the staphylococci.

COMBINED TREATMENT

Theoretically the most effective way of preventing the development of resistant bacteria would be the use of two drugs that would attack two different metabolic pathways of the same organism Many different combinations have been used. Obviously when we are dealing with agents which can attack all of the various susceptible organisms in the body this problem can become very complex.

Jawetz and Gunnison divide antibiotics into 2 general classes

"Group 1 (bactericidal) penicillin, streptomycin bacitracin and neomycin.
Group 2 (bacteriostatic) aureomycin, chloramphenicol and terramycin "[27]

They stated that, "combinations with Group 1 are often synergistic Within Group 2 they are no more than additive. Combinations of the two groups are apt to be antagonistic the Group 2 drug interfering with the bactericidal action of the other Such antagonism is observed only when the organism is fully sensitive to the bactericidal component if it is more resistant (although naturally not if completely so) the combination may actually be synergic."

They strongly emphasize that "no general rules about synergism and antagonism can be laid down The same pair of antibiotics may exhibit either effect against different organisms, according to their degrees of sensitivity Other authors have found that the same pair may be either synergic or antagonistic against the same organism according to the concentration used."

"The whole of this subject has in fact been over simplified, apparently for the sake of brevity by omitting mention of many factors which have been shown to determine the results of combined action."[28]

Garrod emphasizes that laboratory studies are absolutely essential in the care of any given case[29] These are time consuming and at the present time are prohibitive on a large scale He cites "one case of enterococcal endocarditis which occupied well over 100 hours of laboratory time " He remarks on the complexity of the problem, especially when more than one drug is used He states

"The bacteriologist who tackles individual problems of this kind seriously is facing what I believe to be the most complicated task in the whole of routine laboratory medicine "[29]

Dowling suggested some basic precepts governing the joint use of the different anti microbial agents

1 Combinations should not be used in a "shotgun" fashion on the theory that if one agent is effective, 2 or more should be proportionately more effective. In many cases, a single broad-spectrum antibiotic, such as oxytetracycline, will prove more efficacious in treating mixed infections than a combination of less versatile drugs.

2. Where combinations of antimicrobial agents have been demonstrated to be of value in a given disease, these same combinations may be used routinely in all cases of the disease.

3 Where individual agents have been found ineffective in the treatment of a given patient's infection or when resistance of the organism to the agent is demonstrated in vitro tests should be made in vitro to find an effective combination of agents[30]

Gould, Bowie and Cameron remarked about the reliance on sensitivity tests which were qualitative only and in their experiments attempted to correlate the therapeutic doses of the antibiotics and the resulting in vivo concentrations with the results of in-vitro sensitivity estimations. In their study with urinary-tract infections they concluded that "if the dosage of an antibiotic is based on the in vitro sensitivity of the infecting microorganism it will often be much lower than the standard dosage There is reason to suppose that if no more than the lowest effective dose is used the infecting organism is unlikely to become resistant to the antibiotic"[31]

Weil and Harris reported a series of 330 consecutive in-vitro tests in which they observed a high incidence of uncommon bacteria or of bacteria with an unexpected antibiotic "spectra" among their findings.[32] They stated

> A full 3rd of our isolations of organisms of the colon group of proteus and of pyocyaneus bacilli came from locations where these organisms are not commonly found, such as blood cultures, meningitis and osteomyelitis. As to positive blood cultures, only 2 concerned beta hemolytic streptococci and 4 S. aureus, but 6 concerned alpha hemolytic streptococci or S fecalis, 5 members of the colon group 1 proteus, 1 B alkaligenes, 2 H influenzae, type b and 1 Ps. aeruginosa. If one subtracts from these 22 cases the 8 where the clinical aspect of the disease (endocarditis or meningitis) gave some indication of the probable causative agent, 14 cases remain where the tentative diagnosis was septicemia of unknown origin. Seven of these yielded gram-negative rods. Of 9 cases of meningitis 6 concerned H influenzae, type b and 1 each Neisseria meningitidis, E. coli and S aureus.

They referred in an addendum to the work of Chabbert of the Institut Pasteur de Paris concerning "the wide variation of sensitivity not only to penicillin but also to the other antibiotics and the increased finding of resistant strains among gram-positive cocci and enterobacteriaceae from the hospital material obtained in recent years"

From these facts it can be seen how essential sensitivity tests are and it leads us to hope fervently for someone to develop a simpler method of not only qualitative but quantitative determination, so that we will have an index for dosage in each case Of course variation of sensitivity tests to the same organism in different laboratories is understandable from the facts mentioned previously

A number of other reports support Weil and Harris findings of organisms otherwise not considered pathogenic appearing in tissues of the body where they are not found commonly during or following antibiotic therapy especially with broad-spectrum antibiotics

Statistics on resistance of organisms to individual drugs can be confusing. Usually they are limited to certain groups or hospitals in local areas, and to my knowledge there have been no nationwide or worldwide statistics published It probably will take many years to achieve this The following examples will serve to show the trend.

Wellman in 1952 noted that before 1944 very few strains of penicillin-resistant *Staphylococcus aureus* were reported.[33] In 1946 14 per cent were reported 59 per cent in 1948 and 68 per cent in 1949

Needham and Nichols reported in 1953 that prior to 1948 no strains of streptococci were found resistant to Aureomycin.[34] Subsequently the incidence of resistant strains to Aureomycin and Terra-

mycin had increased gradually until in November 1951, they had reached 36 per cent in their series and in January 1953, 45 per cent.

The Veterans Hospital in the Bronx, N Y reported resistance to penicillin by *Staphylococcus aureus* as 59 per cent in 1949 and 80 per cent in 1952 to Aureomycin, none in 1949 and 29 per cent in 1952 to Terramycin, 1 per cent in 1950 and 29 per cent in 1952 to streptomycin none in 1949 and 25 per cent in 1952[35]

SUMMARY AND CONCLUSION

The author has attempted to present a broader outlook on antibiotics and chemotherapy than generally is given in our clinical journals and a review of the best known of these agents their origin characteristics how they act how bacteria develop resistance the problems of sensitivity tests and some of the complications that may arise due to the use of these agents Their specific uses are well known, but many factors are not so well known and an effort has been made to try to bring some semblance of order out of the confusion in the author's mind and in that of many others with whom he has discussed this subject We are treating the *whole person* when we give these drugs and we should know something about how they affect his *whole bacterial population* in addition to the pathogen we are trying to combat

1 Further intensive studies which require the skill of many researchers in bacteriology physiology biochemistry and pathology and of clinicians are being carried out all over the world on the pathology the physiology the biochemistry the genetics etc. of bacteria So many factors can influence the results of these experiments and the *whole picture* is so broad that it often takes many years to interpret all the findings and to evaluate them properly Language barriers prevent closer co-operation in many instances

2 Extensive research studies are being carried out on the various bacterial species, their normal basic characteristics, their reaction to environment, normal or otherwise, and to foreign agents such as antibiotics and chemotherapeutic agents This is a tremendous task in itself. It is necessary to know their normal behavior in their normal habitat, e g in the eye the ear the nose, the throat and the entire gastro-intestinal tract etc Much has been learned along this line but all of the factors that contribute to a "symbiotic state" in the bacterial flora of the gastro-intestinal tract alone in "normal" health are not known Even now the bacteriologist is a most important member of our diagnostic and therapeutic team and will become more so in the future

3 Mutant strains can be transmitted from one person to another and remain resistant to one or more of these therapeutic agents This has created a big problem in the control of venereal disease e g the gonococcus which is resistant to sulfa and penicillin may be transferred and remain resistant. *Recently the broad spectrum antibiotics have been used but not until they were made available for intramuscular injection where they were very effective* As we have seen, soon these probably will become more resistant to the broad-spectrums as well It is hoped that they may revert and again become sensitive to penicillin or the sulfonamides or both.

4 *Resistance to the various drugs is occurring too rapidly to rely on the hope that forthwith a new drug will be made available to handle any specific problem in the future* In any given case if the patient does not respond satisfactorily within the first 48 to 72 hours to any one or a combination of drugs the drug should be stopped and the case re-evaluated. Additional cultures taken as often as necessary will be of tremendous help

5 Further research should be intensified in developing more accurate and simpler sensitivity tests Some of the work on sensitivity tests has been referred to they have brought out many heretofore unknown or

unsuspected strains of bacteria found pre dominant in unusual locations *Quantitative tests are new but will be of tremendous help to us if and when they are improved to such a state that they can be used in a general hospital* The present methods are so cum bersome and time-consuming that they are not practical at the present time

6 It is pointed out that the present media used for sensitivity tests is unsatisfactory with the sulfonamides, as certain chemicals especially the aminobenzoic acid group including PABA, inhibit the action of sulfa even when present in small quanti ties This also should be considered in giv ing drugs containing the aminobenzoic acid group in the treatment of a case

7 Further work on the possibility of using a *chemical agent in conjunction with antibiotics* to enhance their action or retard the development of resistance should be en couraged. It is well known that the use of urea enhances the effectiveness of sulfona mides in vitro and when used locally in wounds The use of PAS with streptomycin enhances the effectiveness of the streptomycin and delays the usually rapid development of resistance to this drug by the tuber cle bacillus

8 Allergic and anaphylactic reactions to these drugs were mentioned only briefly In order to understand the complexity of these problems better consult Dorland's *Medical Dictionary* 22nd edition (1951) and look up the definitions of *allergy anaphylaxis antigen and antibody* one readily can see how many tremendous problems confront us, even in such a small field as the scope of this paper represents

9 Combined therapy has been discussed, and it can be seen that there is no "easy" way to determine which combination is best in any given case Some general rules are presented.

10 An analogy of the problems in entomology has been presented Their experiences are showing the way we are headed even now

These are wonderful drugs we are dealing with but they should be treated with the proper respect. *They never should be used in minor ailments* We should *save our ammunition* for more serious or critical problems. *We should know the organism* that we are trying to combat and select the proper drug by sensitivity tests They should be considered as *precious tools* to supple ment sound medical and surgical judgment.

I desire to express my gratitude especially to Dr Vincent R. Saurino Assistant Professor of Bacteriology University of Miami Medical School, for his invaluable advice and sugges tions in the summarization of the section on the theories on how bacteria are killed by these agents and how they develop resistance. I also wish to thank Dr D O Wolfenbarger * Research Entomologist at the Subtropical Experimental Station Homestead Fla., for his aid in providing additional source material and his help in co-ordinating the material that I had collected in the field of entomology in order to show an analogy of their problems as compared with ours.

* Immediate Past President of the Florida En tomological Society

REFERENCES

1 Palm, C. E. The growing responsibility of entomology to human welfare, Presidential Address, First Annual Meeting J Economic Entomology 47 1 1954

2. Wolfenbarger D O Entomologist, Subtropical Experimental Station Homestead, Fla. Personal communication

3 Brunson, M H and Allen H W Joint use of parasites and insecticides for control of the Oriental fruit moth, J Economic Entomology 47 147 1954

4 Allen, R. F Personal communication

4a —— A study on the effect of terramycin on the intestinal flora Am. J Surg. 86 628 1953

5 Spink, W W Sulphonamide Therapy p 15 Chicago Yr Bk. Pub 1942

6 Sophian L. H., Piper D L., and Schnel ler G H The Sulfapyramidines, pp 78-79 New York Press of A Colish, 1952.

6a. —— Ibid., p 70

7 Mayer P S., Mosko M M Shutz, P J., Osterman, F A Steen, L. H., and Baker L. A. Penicillin anaphylaxis, J.A.M.A. 151 351 1953

8 Duggar B M Ann New York Acad. Sc 51 177 1948

9 Aureomycin—A Review of the Clinical Literature, p 69 Lederle, 1950
10 Dearing W H., and Heilman, F R. Micrococcic (staphylococcic) enteritis as a complication of antibiotic therapy its response to erythromycin, Proc. Staff Meet., Mayo Clin. 28 121 1953
11 Claudon D B., and Holbrook A. A. Fatal aplastic anemia associated with chloramphenicol (Chloromycetin) therapy J.A M.A. 149 912 1952
12 Smiley R. K., Cartwright, G E., and Wintrobe, M M Fatal aplastic anemia following chloramphenicol (Chloromycetin) administration, J.A.M.A 149·914 1952
13 Sturgeon, P Fatal aplastic anemia in children following chloramphenicol (Chloromycetin) therapy J.A M.A 149 918 1952
14 Rich M L. Ritterhoff R S., and Hoffmann, R J Fatal case of aplastic anemia following chloramphenicol (Chloromycetin) therapy Ann Int. Med. 33 1459 1950
15 Finland, M The present status of antibiotics in bacterial infections, Bull New York Acad. Med. 27.216 1951
16 Jackson G G Haight, T H., Kass, E. H., Womack, C R. Gocke T M and Finland, M Terramycin therapy of pneumonia clinical and bacteriologic studies in 91 cases, Ann. Int. Med. 35 1175 1951
17 Hay P and McKenzie, T Side effects of oxytetracycline therapy Lancet 1.945 1954
18 Hofer J B and McCaskey G M Arch Int. Med. 35 1175 1954
19 Woods D D Brit. J Exper Path. 21 74 1940
20 White H J J Bact 38.549 1939
21 Saurino V R. Asst. Prof Bact., University of Miami Medical School Miami Fla. Personal communication
22. Shaw E. Antimetabolites a review Metabolism 2 103 1953
23 Umbreit, W W and Oglinsky E. L. The mode of action of antibiotics penicillin and streptomycin, J Mt Sinai Hosp 19 175 1952
24 Wong, D T O., Barban, S., and Ajl, S. J Inhibition of respiration by aureomycin and terramycin Antibiotics & Chemother 3 607 1953
25 Marmur J., and Saz, A. K. The inhibition of adaptive *enzyme formation in Escherichia coli* by chloramphenicol, Antibiotics & Chemother 3 613 1953
26 Monnier J J., and Schoenbach, E. D The resultant sensitivity of microorganisms to various antibiotics after induced resistance to each of these agents, Antibiotics & *Chemother 1 472, 1951*
27 Jawetz, E. and Gunnison J B Antibiotics & Chemother 2.243 from Garrod Group of Antibiotics.
28 Jawetz, E. Gunnison J B., and Speck, R. S Studies on antibiotic synergism and antagonism Am. J M Sc 222 404 1951
29 Garrod, L. P Combined chemotherapy in bacterial infections Brit. M J pp 953-956 May 2, 1953
30 Dowling. H F The present status, Antibiotics & Chemother 1 2, 1951
31 Gould J C Bowie, J H and Cameron, J D S. Dosage of antibiotics. Relation between the in vitro and in vivo concentrations effective in urinary tract infections, Lancet 1 361 1953
32 Weil A J and Harris, L. Testing for antibiotic sensitivity in a general hospital, Ann. Int Med 38.5 1953
33 Wellman, W E. Postgraduate Medicine 12.167 1952.
34 Needham, G M and Nichols, D R J Lab & Clin. Med 41 150 1953
35 Kenney M et al A four year study of bacterial sensitivity to antibiotics, Antibiotics & Chemother 5 1221 1953
36 Council on Pharmacology and Chemistry J.A.M.A. 137 691 1948
37 Herfort, A Osteomyelitis of the lumbar vertebrae due to *Escherichia coli* J.A.M.A. 150·1073 1952
38 Council on Pharmacology and Chemistry J.A.M.A. 141.264 1949
39 Sweetman, H L. The Biological Control of Insects, Ithaca, N Y Comstock, 1936.

10

The Local Use of Hydrocortisone Acetate in the Treatment of Painful Shoulders

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The frequent use of needling procaine infiltration, repeated manipulation, roentgenotherapy and daily forced passive stretching is mute evidence that the painful shoulder still presents many puzzling problems. It has not been too many years since all pain about the shoulder joint was classified by most physicians as bursitis In the process of continued study a group of rather definite disease entities was evolved Codman did much to make us more aware of the importance of arriving at some definite diagnosis in shoulder lesions [2] He classified chronic tendinitis in the abductor cuff tendons with calcareous deposit. For some time this was considered to be the most frequent cause for shoulder pain and disability Tenosynovitis of the tendon of the long head of the biceps muscle was mentioned early as a possible cause of shoulder disorders More recently DePalma clarified this lesion and demonstrated its importance in the production of shoulder disabilities [3] Causalgia or sympathetic dystrophy of the extremity resulting from cervical spine radiculitis also has been demonstrated as a not uncommon cause of disabling pain in the shoulder [9] Other lesions, such as acute trauma and acute or chronic synovitis, also may be etiologic factors

Regardless of the cause the sequence of events in painful shoulders is relatively constant when adequate treatment is not instituted during the early stages. The pain accompanying all of these lesions results in loss of shoulder function and an ensuing muscle atrophy As stated by DePalma, this causes a slowing down of the circulation and results in venous and lymphatic stasis A low grade chronic inflammatory process follows which affects all tissues about the shoulder This inflammatory process unless prevented or cleared up eventually will result in a frozen shoulder Pain will persist until all inflammation has subsided DePalma has pointed out that tenosynovitis of the tendon of the long head of the biceps muscle is the most common and tenacious complication of shoulder lesions

It has been agreed rather generally that it is necessary first to relieve the pain factor in the shoulder if one is to restore its function. In the past the gamut of conservative measures has been run with unsatisfactory results in a large percentage of the cases If all pain has subsided, the frozen shoulder may respond to gentle manipulation under anesthesia however if the inflammatory process still exists such therapy will only aggravate the process Surgery to remove the calcareous deposits or decompress the tendinitis and transplantation of the tendon of the long head of the biceps muscle have given very good results. This

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type of treatment always requires hospitalization, and the convalescence often continues for a long period of time

Since the chronic inflammatory process about the shoulder has been established as the causative factor in the continuance of the disability, attention has been focused on some conservative measures that would clear up the process The development of cortisone and later hydrocortisone acetate made available an anti inflammatory substance that had promise in decreasing or clearing up the joint inflammation Hollander and his associates found that hydrocortisone was much more effective than cortisone when used locally in the joints and other involved tissues.[4] Their experiments revealed that hydrocortisone is much less soluble in blood plasma and thereby remains local in a greater concentration for a much longer time In addition it did not produce the local irritation that was produced by cortisone Subsequently Hollander reported a large series of cases of arthritic and allied conditions treated by local injection with very good results[5,6] Comparable results have been reported by other authors.[11,12,13] A few reports have been published on its local use in nonarthritic joint lesions and tenosynovitis Howard Pratt and Bunnell reported good results when it was used locally in lesions about the hand, including tenosynovitis[7] Orbach reported 6 cases of so-called bursitis of the shoulder all of which subsided quite promptly[8] Recently Butson reported on its use in subdeltoid bursitis and frozen shoulders along with its use for other local joint conditions[1] His report indicated approximately 56 per cent of good results in these two shoulder lesions. It should be noted here that he injected the material either into the joint or into the subdeltoid bursa in all of the cases In a most recent paper Reynolds and Ramsey reported excellent results from its use in acute subdeltoid bursitis with or without calcareous tendinitis however their results in frozen shoulders were much less striking.[10] The conclusion reached in the article was that the material had been injected directly into the joint in the latter group of cases

The cases selected for study in this report have been those in which the primary nature of the lesion was not inflammatory Rheumatoid arthritis and allied conditions which are primarily inflammatory diseases were excluded because past studies have shown that hydrocortisone will decrease or clear up the local process in other diseases but that the condition will recur unless the arthritic process as a whole subsides along with the clearing of the injected joint. We were interested in determining whether or not hydrocortisone when used locally in inflammatory tissues that occurred primarily as a result of venous and lymphatic stasis, would clear up the inflammation and whether or not it would remain cleared Since pain is associated directly with the inflammatory process in the group of painful shoulders under discussion, one would expect the inflammation to subside with re

TABLE 1 ANALYSIS OF CASES SELECTED FOR TREATMENT (24 CASES)

Diagnosis	No of Cases	Status of Shoulder Motion: Normal	Partially Stiff	Frozen
Sympathetic Dystrophy (Shoulder Hand Syndrome)	4			4
Calcareous Tendinitis	10	5	4	1
Noncalcareous Tendinitis	2	1	1	
Trauma (Sprain and Acute Synovitis) *	5	1	2	2
P O Radical Breast Surgery (X ray Therapy)	2			2
Primary Biceps Tenosynovitis	1			1
Total	24	7	7	10

* One case of fracture of the greater tuberosity and 1 case of fracture of the surgical neck of the humerus.

lief of the pain and restoration of function. DePalma has demonstrated that this is true by transplanting the tendon of the long head of the biceps muscle from its groove to the coracoid process of the scapula In our study no attempt was made to grade the severity of the pain however the status of passive motion was graded on the basis of normal, partially stiff and frozen. It is interesting to note that we are able to separate only 1 case in which we could make a primary diagnosis of biceps tenosynovitis (Table 1) However when the patients were examined, 13 were found to have a biceps tenosynovitis that had developed during the course of the disease (Table 2) This indicated to us that the inflammatory process that occurs as a result of functional loss in the shoulder involves the tendon of the long head of the biceps most frequently

In the treatment of painful shoulders with hydrocortisone, it was felt that it was essential to localize the cause of the pain accurately This became necessary because hydrocortisone remains localized quite well and does not diffuse into all tissues about the shoulder Injection into the shoulder joint will not result in diffusion around the biceps tendon in the presence of adhesions Therefore in all of our cases the material was injected directly into the tendon sheath or other tender and painful areas The quantity required to give relief was found

TABLE 2. ANALYSIS OF CASES WITH SECONDARY BICEPS TENOSYNOVITIS

Primary Diagnosis	No of Cases	Status of Shoulder Motion		
		Normal	*Partially Stiff*	*Frozen*
Sympathetic Dystrophy	3			3
Calcareous Tendinitis	2		1	1
Noncalcareous Tendinitis	2	1 mild	1	
Trauma	4			4
P O Radical Breast Surgery (X-ray Therapy)	2			2
Total	13	1	2	10

TABLE 3 ANALYSIS OF RESULTS FROM LOCAL INJECTION OF HYDROCORTISONE

Diagnosis	No of Cases	No of Injections	Results: *Relief of Pain*			*Return of Motion*		
			Failure	Improved	Relieved	None	Partial	Normal
Sympathetic Dystrophy	4	8		1	3		1	3
Calcareous Tendinitis	10	23		2	8		1	9
Noncalcareous Tendinitis	2	2		1	1		1	1
Primary Biceps Tenosynovitis	1	2			1			1
Trauma	5	7			5		1	4
P O Radical Breast Surgery X-ray Therapy	2	3			2		1	1
Total	24	45		4	20		5	19
Secondary Biceps Tenosynovitis	13	25		2	11		3	10

to be small At first we used larger doses but later we found that it was rarely necessary to use more than 25 mg. in both the tendon sheath of the long head of the biceps muscle and the shoulder joint, dividing it equally between the two areas Twenty five mg. was the amount injected in the tendinous cuff and the subdeltoid bursa in cases of calcareous tendinitis The injections were repeated if the pain recurred or if it had not cleared up entirely following the first injection Injections were not continued after relief of pain Procaine was used only to infiltrate the skin. Eleven of the cases required only 1 injection while there was 1 case that required more than 4 injections The 24 cases received a total of 45 injections All of the cases were followed for at least 3 months except for 3 cases of acute calcareous tendinitis

In evaluating the results in these cases they have been graded on the basis of pain relief and restoration of active motion or functional use of the shoulder The results have been tabulated in Table 3 The results were based on findings at the time the study was made The duration of improvement or complete relief had continued for from 3 months to 15 months except in the 3 cases of acute calcareous tendinitis seen more recently There was not a case in which material improvement had not been obtained More than 80 per cent had received complete pain relief Motion also was improved in all cases and normal motion was obtained in 19 however it should be noted that 5 cases had normal motion before treatment. Some interesting features were presented by several of the cases One of the patients had suffered for several years with pain in the left side of the neck, the shoulder and the arm which was associated with extensive degenerative arthritis of the cervical spine The left shoulder became stiff about 1 year prior to admission. It had been manipulated twice without any improvement. At the time of our first examination there was marked tenderness over the tendon of the long head of the biceps muscle with only a few degrees of very painful motion. Twelve and one half mg. of hydrocortisone was injected into the sheath of the biceps tendon and 12½ mg. directly into the shoulder joint. Two days later the acute pain had subsided, and active and passive motion was begun The injections were repeated after 1 week. Practically all of the discomfort disappeared following this injection The motions were nearly normal at the end of 5 weeks Two days later the patient fell on the ice and sustained an undisplaced fracture of the greater tuberosity There was a mild recurrence of the biceps tenosynovitis following this injury but this subsided after 2 injections of hydrocortisone The patient now has a well functioning shoulder Another patient with a chronic calcareous tendinitis had been given hydrocortisone systemically for 5 months with practically no improvement. At the time of examination the tendinitis was found to be complicated by a biceps tenosynovitis Both of these responded promptly to the local injections. Full motion had returned by the sixth week. One other patient with a chronic calcareous tendinitis complicated by a biceps tensynovitis responded much more slowly The calcareous deposits in this patient involved the whole cuff and the tendons of both the supraspinatus and the infraspinatus muscles The relief from pain was always good but lasted for only about 1 week at first. The duration gradually increased with subsequent injections. The last injection was approximately 8 months ago The patient was free of pain at this time and had about 90° of motion in the shoulder It should be noted that this case had received 2 courses of roentgenotherapy with only slight relief prior to the local injections of hydrocortisone.

DISCUSSION

The consistent anti inflammatory action of hydrocortisone acetate has been demonstrated by many authors The results will be more favorable in those cases in which the process is self-limited namely one that

when cleared up is not likely to recur Such a condition exists in most painful shoulders Reports on the use of hydrocortisone acetate in acute lesions of the shoulder have been excellent however the results in the chronic lesions, particularly frozen shoulders have not been striking A careful study of these latter reports fails to reveal the specific location or nature of the lesions in these cases The results obtained in a study of our cases indicates that this is necessary because the hydrocortisone must be injected directly into the inflamed area Failure to accomplish this will not clear up the process Some of these cases have generalized capsulitis with little involvement of the adjacent tissues. These cases respond well to injections of the material into the joint. On the other hand, we found that it was necessary to inject directly into the sheath in the presence of a biceps tenosynovitis

The only complication encountered in our cases was increased pain for several hours after the injection in a few cases This did not cause any concern because it was followed by good pain relief within 24 hours The increased pain did not recur with a second injection. We did not consider this a contraindication to repeated use of the drug. The only known contraindication to its use is the presence of an infection. All of our cases were screened carefully and thus far we have not injected any known infected areas

CONCLUSION

We have presented a series of painful shoulders that were treated by the local injection of hydrocortisone In this study the necessity of injecting the material directly into the inflamed tissues is emphasized. In order to accomplish this, an accurate diagnosis and localization of the lesion is necessary before beginning treatment. The number of cases reported is too small to draw any definite conclusions however they are striking enough to indicate that the treatment, when correctly used may offer the best available treatment for such lesions

REFERENCES

1 Butson, A. R. C. Intra articular hydrocortisone in orthopedic conditions, Canad. M A. J 70.51 1954
2 Codman, E. A. The Shoulder Boston Thomas Todd 1934
3 DePalma, A. F Surgery of the Shoulder Philadelphia Lippincott, 1950
4 Hollander J L., Brown E. M Jessar R. A., and Brown, C. Y Hydrocortisone and cortisone injected into arthritic joints, J.A M.A. 147 1629 1951
5 Hollander J L. Intra-articular hydrocortisone in arthritic and allied conditions, J Bone & Joint Surg. 35A.983 1953
6 —— Intra-articular hydrocortisone in the treatment of arthritis, Ann Int. Med 39·735 1953
7 Howard, L. D Pratt, D R. and Bunnell, S The use of Compound F (Hydrocortone) in operative and non-operative conditions of the hand, J Bone & Joint Surg. 35A.994 1953
8 Orbach, E. J Treatment of bursitis by local injections of hydrocortisone acetate J Internat. Coll Surgeons 18 159 1952.
9 Overton L. M Degenerative changes in the cervical spine as a common cause of shoulder and arm pain, South. Surgeon 16 599 1950
10 Reynolds, C. F and Ramsey R. H. The use of hydrocortisone (Compound F) in orthopedic surgery South. M J 47.209 1954
11 Stevenson, C. R., Zuckner J and Freyberg, R. H Intra-articular hydrocortisone (Compound F) acetate Ann. Rheumat. Dis. 11 112, 1952.
12. Young, H. H., Ward, L. E., and Henderson, E. D J Bone & Joint Surg. 35A 1033 1953 (Proc. Am. Orthop A. Annual Meeting 1953)
13 Ziff, M., Scull, E., Ford, D., McEwen, C., and Bunim, J J Effects of intra-articular hydrocortisone acetate on the clinical course, aminotripeptidase activity and other changes in the synovial fluid in rheumatoid arthritis Ann. Rheumat. Dis. 11 301 1952 (Proc. Annual Meeting Am Rheumat. A., 1952)

11

Heel Modifications as Aids in Rotation Control

JOSEPH D GODFREY, M D

With the ever increasing levels of intelligence of parents and with keenness of observation and awareness of poor postural sequelae we are more alert to gait abnormalities than ever before Their correction must never be left to the shoe clerks and the cobblers.

In the early toddling and walking days of the infant the pattern is usually one of broad base external rotation feet pronation and plodding As the infant develops, heel and toe gait elements appear in the pattern, and when the heel makes contact the foot is normally in dorsiflexion with the knee fully extended and the extremity at maximum length

Where and when the heel and toe pattern of walking is established, it may be said with reasonable certainty that factors above calcaneal level come into play to rotate the foot internally or externally as the case may be for the half-circle rounding of the posterior portion of the average heel provides the easy to-roll walking surface contact. This fundamental pattern makes possible the rotation control aids described below

It is not within the scope of this practical presentation to discuss foot imbalances tibial torsions, genu valga or genu vara etc but suffice it to say that these are aided by the modified heels Obviously local treatment for the imbalanced foot is in order In this particular paper we deal more with rotation components secondary to habits rather than with deformities

Such habits as sitting on one foot or both feet with one or both in forced internal rotation sleeping in the curled-up buttocks high, knee-chest position, sleeping face down with the lower extremities rotated internally and the feet in equinovarus and the like should be corrected by training, policing and splinting

The use of flared or winged heels occurred to the author as possible aids in fostering internal or external rotation Contact of the rounded heel as previously noted, permits an internal or an external rotation roll as the full plantar surface of the shoe, striking heel first, approaches the walking surface. The straight contacting edge of the flared or the squared heel exerts a stabilizing or hinge action as the forefoot is brought down

The earliest uses of the above principles were in cases of extensive poliomyelitic involvement of the lower extremities, where, when the flail straightbraced leg was swung through heel contact was the first made and unpredictable or poorly controlled rotation of the entire extremity occurred As flarings continued to aid walking patterns their use was extended into indicated channels. Doubly flared or squared heels were attached to foster neutral patterns.

It is obvious that desired corrective rotations are fostered when the child is in a sitting position on a level surface

Overshoes and rubber footgear pose a fitting problem but some parents merely get large enough sizes

In the construction of the special heels

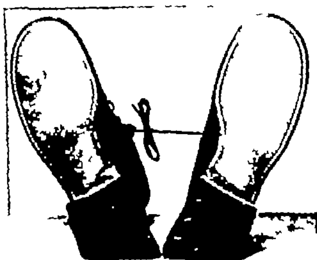


Fig 1 The medial flares promote external rotation.

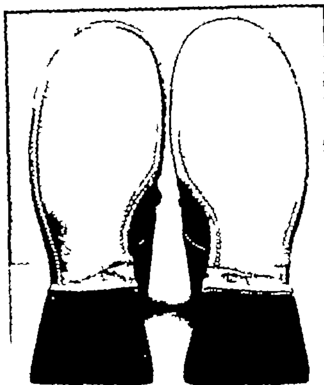


Fig. 3 The doubly flared promote neutral patterns.

it is recommended that metal plate reinforcement be used, because leather will curl at the first contact corner, and efficiency decreases Aluminum sheeting, known to the trade as ALCAD 75 S has been used by the bracemaker for it may be worked easily while being stout enough to withstand the poundings of youth Leather or rubberoid compositions are shaped and cemented to the plantar face of the plate Parents are advised to replace the leather or the rubberoid composition when indicated, so that the plate does not wear to a knife edge

These alterations have been employed in over 100 instances during the past 2 years. In only 1 case has a parent thought that they were of no value and in that instance her opinion was reversed at an examination

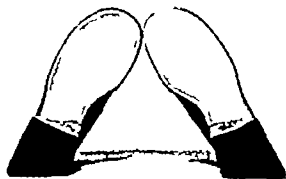


Fig. 2 The lateral flares promote internal rotation.



Fig. 4 The squared heels also promote neutral patterns.

within the week prior to submission of this paper for publication. These modifications are proposed as aids and not answers to rotation control problems

BIBLIOGRAPHY

Baker Lenox D The foot and ankle symptoms, pathology and diagnosis in Regional Orthopaedic Surgery and Fundamental Orthopaedic Problems, p 8 Ann Arbor Edwards Bros 1947

Diveley Rex L. Foot appliances and shoe alterations in Orthopaedic Appliances Atlas, Ann Arbor Edwards Bros. I 439 1952

Fisher Walter R. Practical foot problems in Instructional Course Lectures, American Academy of Orthopaedic Surgeons, Ann Arbor Edwards Bros. 5 153 1948

Goff Charles Weer Posture in children in Clinical Orthopaedics Philadelphia, Lippincott 1 66 1953

Hauser Emil D W Disorders of the Foot, Philadelphia, Saunders, 1950

Howe, W W Goldstein, L. A. and Schwartz, R. P Internal Rotation of the Tibia, presented at the American Academy of Orthopaedic Surgeons, Twenty First Annual Meeting Chicago 1954

Inman, Verne T The major determinants in normal and pathological gait, J Bone & Joint Surg 35A.543 1953

Kendall H. O Kendall, F M., and Boynton, D A Posture and Pain, Baltimore, Williams & Wilkins 1952.

Kite J H Torsion of the lower extremities in small children J Bone & Joint Surg. 36A. 511 1954

Knight, Robert A Developmental deformities of the lower extremities, J Bone & Joint Surg. 36A.521 1954

Levens A. S., Inman V T., and Blosser J A. Transverse rotation of the segments of the lower extremity in locomotion, J Bone & Joint Surg. 30A 859 1948

Lewin, Philip Infantile Paralysis, Anterior Poliomyelitis, Philadelphia, Saunders, 1941

McKeever Duncan C Interpretation and treatment of weight bearing defects in apparently healthy children in Clinical Orthopaedics, Philadelphia, Lippincott I 56, 1953

Morton Dudley L. Physiological considerations in the treatment of foot deformities, J Bone & Joint Surg. 19-1052, 1937

Schwartz, R. Plato and Heath, Arthur L. Some factors which influence the balance of the foot in walking, J Bone & Joint Surg. 19-431 1937

Shephard Edmund Tarsal movements, J Bone & Joint Surg. 33B.258 1951

Steindler Arthur The pathomechanics of the static disabilities of foot and ankle in Instructional Course Lectures, American Academy of Orthopaedic Surgeons, Ann Arbor Edwards Bros 9-327 1952.

12

The Preservation of the Function of the Foot Balancing and Synchronizing the Shoe with the Foot

A Critical Analysis of the Conventional Shoe*

HARRY C STEIN M.D †

If preservation of the foot is to be the prime consideration in the design of the shoe it is necessary that the shoe be engineered to comply with the biomechanical principles that govern the action of the foot Any factor of the shoe that obstructs the normal distribution of the dynamic forces of the foot leads to breakdown of the foot.

The design of the shoe for the normal foot is the responsibility of the orthopaedic surgeon. By training and experience he is best qualified to direct that the design of the shoe embody the features necessary to accommodate the biomechanical requirements of the foot.

The intricate and highly complex mechanics involved in foot function have been greatly elucidated as a result of extensive pioneering and painstaking research and literary contributions by such investigators as Duchenne, Meyer Thomas Piersol, Lovett, Whitman Munson, Morton Steindler Elftman, Schwartz and others Harris and Beath, Lewin, Dickson and Dively Hauser and many others.

In spite of this, the design of the shoe continues to be dictated arbitrarily by custom fashion and the whims of the manufacturer rather than by sound engineering principles based upon the biomechanics of the foot. Fashion and common sense are unevenly matched foes

As a result of the faulty relationship existing between the conventional shoe and the foot, gradually we are becoming a nation of "foot-cripples" It is rare to find a pair of feet entirely free from some deleterious influence of the conventional shoe. The combination of hallux valgus, metatarsal breakdown and contracted deformed toes, in varying degrees has become almost universal (Fig. 1) The list of other widespread ailments, primary and secondary directly and indirectly attributable to the conventional shoe is a lengthy one (Table 1 *on following page*)

Primitive and nonshoe wearing peoples have powerful, well-developed and versatile feet with tremendous functional capacity They are practically free from fatigue discomfort, *strain* and the common "foot ailments."

What is there about the conventional shoe that has so plagued civilization? The author became particularly interested in this question as a result of his investigations of the problem of hallux valgus [32] particularly regarding its etiology and postoperative care

* Presented as a scientific exhibit at the American Academy of Orthopaedic Surgeons January 1953 at the Palmer House, Chicago.

† New York, N Y

Prior to the Civil War right and left shoes were made on identical symmetrical lasts. They were interchangeable for either foot. The question of biomechanics never was given serious consideration in their design. When "rights" and "lefts" in shoes first were given to the soldiers, they were considered objects of ridicule and derision because they were not interchangeable. This step marked the beginning of the application of scientific biomechanical principles to shoe design. Since then, progress in basic shoe design has been relatively scant. The shoe in its "evolution" is notorious for its tenacious adherence to old forms. Changes come about in extremely slow moving cycles.

In 1912 Munson published the findings of an extensive investigation of this problem by the Army Shoe Board, of which he was head. This study extended over 4 years and included critical examination of the feet of some 2 000 soldiers and the fitting of thousands of pairs of shoes.

TABLE 1 WIDESPREAD AILMENTS ATTRIBUTABLE TO MALALIGNED UNSYNCHRONIZING SHOES

Arch Strains and Breakdown: longitudinal, transverse
Toe Deformities: hallux valgus, hallux rigidus, hammer and claw toes, overlapping and distorted toes, etc.
Fibrositic Involvement: strained and inflamed muscles, tendons, ligaments, fascia, periosteum
Skin, Appendages: corns, callosities, ingrown toenails, clubnails, bursitides, inflamed fat pads (subastragalar fossa, metatarsal), vasomotor disturbances (hyperhydrosis, "burning," etc.)
Painful Heels: inflamed or thinned fat pads, fasciitis, bursitis, periostitis, spurs
Secondary Arthritic Changes: static, traumatic
Secondary Postural Joint Strains: knee, hip, spine
Secondary Nervous System Strains and Tensions: various neurasthenic and exhaustive manifestations



FIG 1 This combination of hallux valgus, secondary metatarsal breakdown and contracted toes in varying degrees has become almost universal.



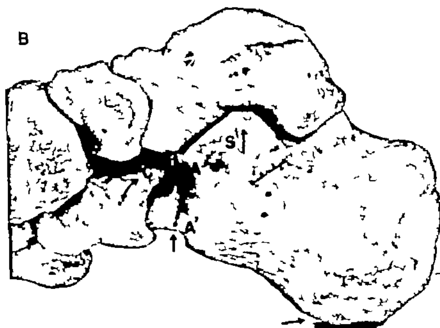


FIG 2 (A) The angulation of the calcaneus, its descent and enlargement, forms the longitudinal arch The arch is asymmetrical The anterior pillar is much longer than the posterior The foot is relatively flat anterior to the point of angulation. The navicular tubercle (T) encroaches on the anterior pillar (B) The angulation of calcaneus (A A) inclines lateralward downward and forward. This causes a corresponding relationship of the peak of the lateral arch to that of the medial The plantar tubercle of the cuboid (C) "locks" the calcaneus. The sustentaculum (S) supports the talus.

The following interesting excerpt from this report is pertinent to the present presentation

The foot is not at all the rigid structure popularly supposed, to be carelessly jammed into any container irrespective of the size shape and character of the latter On the contrary it is seen to be a highly developed member of complex formation and intricate function, every factor of which needs thoughtful consideration in determining its proper covering.[23]

Critical analysis of the conventional shoe reveals a multitude of factors which interfere with the normal distribution of the dynamic forces of the foot and lead to its breakdown.

Before describing these findings and outlining projected modifications for a physiologically balanced and synchronizing shoe it may be relevant to mention some of the more pertinent evolutionary anatomic physiologic and biomechanical factors that govern or have important bearing on the relationship of the shoe to the foot.

ANTHROPOLOGIC CONSIDERATIONS

The evolutionary changes in the human foot well exemplify the operation of Wolff's law of adaptation of the anatomic structures of organs to meet their functional needs

Man alone of the mammals has a longitudinal arch and bears weight on the heels of feet joined at right angles with the legs.

As man in the course of evolution adopted the upright position and the foot assumed the entire burden of weight bearing and locomotion the weight line shifted from the region of the center of the foot to the heel. Among the numerous other adaptive changes of the foot, the body of the calcaneus underwent angulation enlargement and descent (Fig 2 A) This enabled the heel to contact the ground firmly and gain strength. The calcaneus, posterior to the site of this angulation forms the common pier of the thus-created medial and lateral longitudinal arches The line of angulation inclines laterally and obliquely forward (Fig 2 B) This causes the peak of the lateral arch to be lower and more forward than that of the medial

"EVOLUTION" OF THE SHOE

General Considerations

1 Most primitives went barefooted, which toughened the soles of their feet to form a natural protection

2 It is assumed that animal skins and hides first were used as protective footwear by those living in the mountains as hunters in their quest for food.

3 The origin of the shoe has been traced to the third and the fourth pre-Christian millenniums to the first great civilizations in Mesopotamia and Egypt.

4 The common types of footwear—the shoe the sandal the slipper and the boot—were developed in ancient times Sandals are regarded as typically Asiatic shoes as European.

5 Throughout the centuries the shoe has adhered tenaciously to old forms Changes take place in very slow cycles in which utility and fashion alternated in dominating the design of the shoe

6 Fashion, instead of adding a touch of gaiety to the shoe as originally intended, *more frequently assumed a commanding* role. This resulted in the creation of many strange forms of highly impractical footwear

7 The cycles of changes in design of the shoe centered mostly around the shape of its toe section. The variations included open, round, square and oval toes of widths and lengths of varying extremes and pointed toes of varying extremes of sharpness, length and upcurving.

8 Included among the stranger forms of highly impractical footwear appearing in these cycles were pedestals, stilts, pattens, platforms, clogs galoshes chopines, cracowes, poulaines, bundschuh kuhlmaul and the dunder bludgeon.

9 Woven stockings first were introduced A.D 600 Hosiery was worn but little up to this time They were tailored from pieces of hard fabrics the seams of which precluded the use of any but the softer types of footwear With the advent of the woven stocking came the snug fitting and firmer type of shoe This was the forerunner of the present conventional shoe.

10 The thick heel on shoes, although introduced for Caesar's soldiers in the form of a leather stud did not find its way into general use until the sixteenth century, when both it and the heavy sole came into vogue

11 In 1547 Catherine de Medici of Italy came to Paris, as the bride of Henry II wearing high-heeled slippers to increase her stature She is given credit for introducing and popularizing women's high-heeled shoes Men's and women's styles heretofore generally identical now deviated in design the high-heeled shoe becoming typically feminine.

12. Until the beginning of the nineteenth century shoes were custom made with hand tools, first by members of one's own family then by itinerant workers, later in small shops

13 Although crude, hand-hewn lasts were used in making shoes over the centuries it is only within the more recent decades that their importance in foot health has become recognized. They have become a vital force in shoemaking

14 The first machine turned last appeared in 1815 when a lathe for turning out gun stocks was adapted for this use.

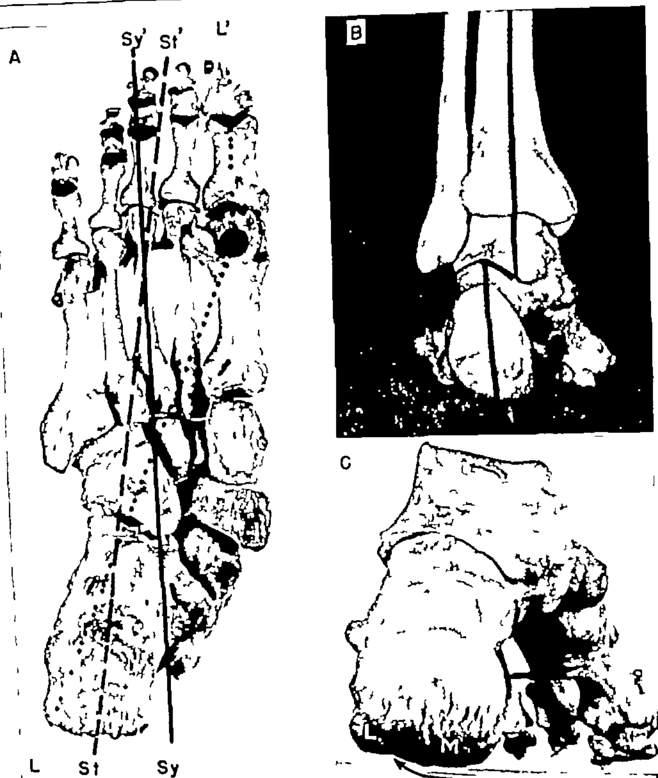


FIG. 3 (A) Note eccentric relationship of calcaneus. Axis of symmetry (of conventional shoe) Sy-Sy axis of standing (also of essential arch and balance) St St The axis of locomotion L L breaks at the ball of the great toe, as sesamoid muscles take over the propulsive effort. (B) The vertical axis of weight-bearing of the calcaneus is offset lateralward about 1 to 1½ cms. from that of the tibia. (Schwartz, R., and Heath A Physiotherapy Rev 16 48) (C) Lateral inferior calcaneal tubercle (L) is smaller and lies posterosuperiorly in relation to the medial (M) Arrow indicates the arc of rotation of the calcaneus in the initiation of gait. The vertical axis of weight bearing shifts correspondingly

It was not until 1844 that a simplified last turning machine and a fixed chart of stand ard last measurements was developed

15 Right and left shoes first were produced in volume for soldiers during the Civil War Although they were referred to as crooked shoes " they enjoyed such popularity that soon they were adopted for civilian use

16 Leather counters first were manu factured in 1845 Shoe tips were introduced in 1858 toe boxes in 1862 rights and lefts in toe boxes in 1906

Thus, the modern snug fitting hard-soled thick heeled shoe in "rights" and 'lefts" is of comparatively recent origin This type of shoe has great advantage in fit protective qualities and appearance over its predecessors the loose fitting soft soled shoes—the moccasin and the sandal Nevertheless, it has a serious disadvantage It does not syn chronize with the action of the foot, thus distorting the normal distribution of the moving load and leading to the breakdown of the foot.

ANATOMIC CONSIDERATIONS

1 The calcaneus is located eccentrically in relation to the foot (Fig 3 A) and the leg Its vertical weight bearing axis is from about 1 to 1½ cm lateral to that of the tibia (Fig 3 B) This anatomic relationship has the mechanical advantage of making possible a rapid shift from the axis of stance to that of locomotion. Mobility is gained at the expense of stability It also favors the direction of the forces of locomotion toward the great toe

2 The angulation of the body of the calcaneus (Fig. 2 B) forms the peak of the medial and the lateral longitudinal arches

3 The medial inferior calcaneal tubercle juts inferomedially to act as a natural strut against its pronation (Fig. 3 B and C) The lateral tubercle (Fig. 3 C) lying posterosuperiorly thereto is of considerably smaller size It serves to check excessive rolling ac tion of the heel in that direction during the initiation of gait.

4 The sinus-tarsi allows for eversion and inversion at the subtalar joints.

5 The plantar tubercle of the cuboid (Fig 2 B) abuts against the calcaneus. In the presence of good stability of the essential arch it acts as a further check against calcaneal pronation.

6 The tubercle of the navicular projects inferiorly, encroaching considerably on the anterior pillar of the medial arch (Fig 2 A)

PHYSIOLOGIC CONSIDERATIONS

1 The foot is an amazing machine In spite of its lightness and elasticity it posesses tremendous strength Unmolested, it bears the estimated enormous daily cumulative force of 704 tons (Table 2) with comparative ease comfort and freedom from trauma, although constantly exposed

2 The remarkable efficiency of its per formance is due to the architectural ar rangement of its 26 bones and 137 joints into multiple elastic arches and levers This permits complete distribution and dissipation of the moving load and provides re sistance to excessive forces It the foot were composed of but 1 or 2 bones the trauma resulting from the undistributed impact against the ground would make walking impossible

TABLE 2 ESTIMATED DAILY CUMULATIVE FORCE, EACH FOOT (FROM QUIMBY)

No of miles individual walks daily	8
No of feet to mile	5,280
No of feet to each step	3
No of steps to mile	1 760
No of steps to 8 miles	14,080
A 200-lb man bears on foot, each step	100 lbs.
14 080 steps	1 408,000 lbs.
Daily cumulative force each foot (Letter carriers, double)	704 tons

3 The skeletal framework with its ligaments provides the main support of the body weight against the forces of gravity The muscular structures serve by their reverse

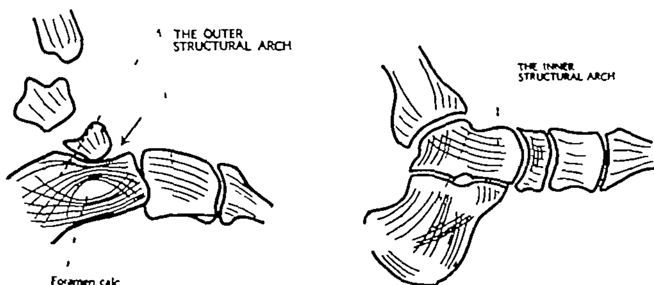


FIG. 4 The bony trabeculae of the foot are arranged to form two distinct trajectory systems These correspond to the medial and the lateral arches. (Steindler A. Mechanics of Normal and Pathological Locomotion in Man, Springfield, Thomas)

FIG. 5 Essential arch (A) Lateral view (B C D) Lateral medial and dorsal views talus and navicular added Note (B D) that the base of the lateral cuneiform articulates with both the cuboid and the navicular bones. This is in accord with the pivotal relationship of the essential arch to both longitudinal arches.

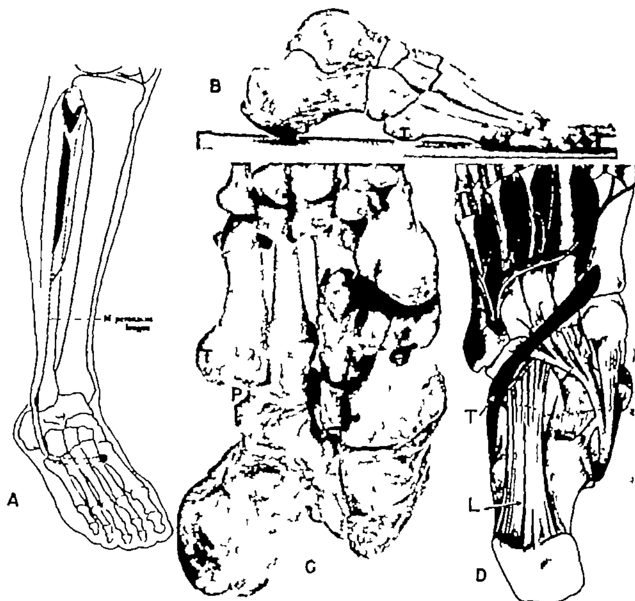


FIG 6 (A) Course of peroneus longus muscle and tendon (the only muscle that forcefully plantar flexes the medial half of the forefoot) (B) The tuberosity (T) forms the fulcrum for the peroneus longus action. It serves as an auxiliary anterior pier adding great comfort in locomotion. (C) The tuberosity at the base of the fifth metatarsal (T) forms the inferolateral wall of the peroneal groove (P) (D) Note the transtarsal course of the peroneus longus tendon (T) and the lateral location of the long plantar ligament (L)

and distal actions to control the skeletal framework in balancing, propulsion and in restraining capacities

4 The distribution of the body weight in the foot is mediated through its skeletal bearing-points If these are unbalanced faulty distribution results

5 The inferior calcaneal tubercles the head of the third metatarsal, the ball" of the great toe and the head and the base of the fifth metatarsal are key bearing-points of the foot.

6 The bones of the foot are arranged anatomically to form two longitudinal arches. The calcaneus forms the common posterior pillar and pier for both. The lateral arch (predominant in standing) is completed by the cuboid and the outer two metatarsals The medial arch (serving chiefly in locomotion) is completed by the

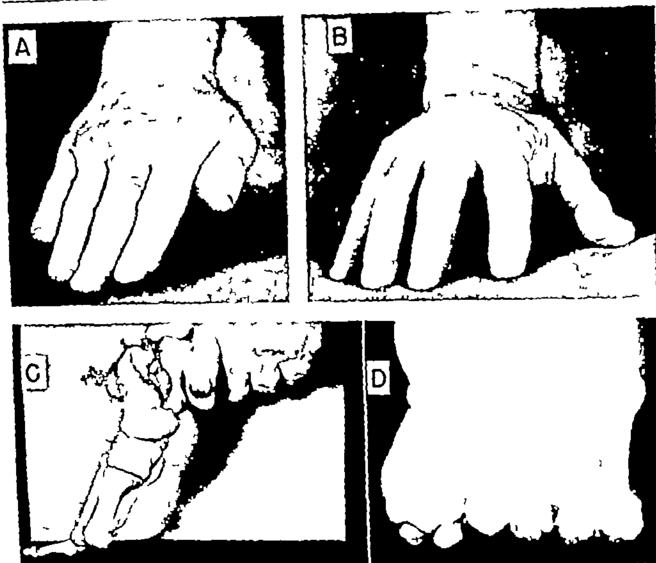


FIG 7 (A, B) Illustrates by analogy the formation of a metatarsal arch as the toes flex. This facilitates the completion of the transfer of the forces of locomotion to the ball of the great toe (C) (Great toe removed) On tiptoes ground contact is made with the bases of the proximal phalanges of the lateral four toes (D) with the sesamoids of the great toe. (Photos A and B from Harris, R. I and Beath, Thomas J Bone & Joint Surg. 31A 553)

talus the 3 cuneiforms and the inner 3 metatarsals The trabeculae of the bones comprising these arches are arranged in the form of 2 distinct trajectory systems (Fig. 4) The base of the lateral cuneiform articulates with both navicular and cuboid bones (Fig 5 B and D) The third metatarsal head, although anatomically a component of the medial arch physiologically serves both longitudinal arches Forming the anterior pier of the essential arch it participates in the support and the balance of the body weight in standing. It also serves as a pivot, to assist in the shifting of the body weight from the lateral to the medial arch in locomotion.

7 The essential arch (Fig 5 A) is formed by the calcaneus the cuboid, the lateral cuneiform (joined to the last by a firm interosseous ligament) and the third metatarsal bone

In the ordinary position of supporting the body it appears that the essential arch is through the calcaneus the cuboid the lateral cuneiform, joined to the latter by a firm interosseous ligament, and the third metatarsal This can be proved by removing the first and the fifth metatarsals without impairing the stability of the foot. The fourth metatarsal may

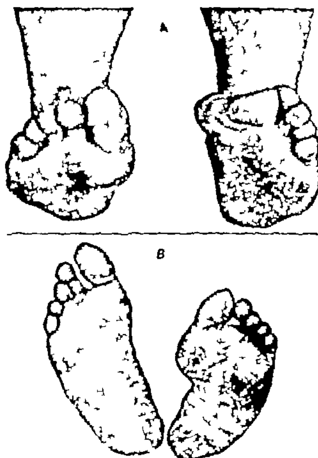


FIG 8 Illustrates the importance of torsion in maintaining equilibrium (same is true physiologically) (A) Flat foot (*left*) Forefoot in supination as compensation for pronation of hind foot (else it would dig into the ground) (B) Claw foot (*left*) Forefoot pronated to compensate for supination of hind foot (in order to reach the ground) (Boehler L. Treatment of Fractures Fourth English Edition Groves Baltimore Wood)

next be taken away without trouble If the second with its cuneiform be detached with care the arch is still reasonably firm. It is possible to preserve the arch after taking out the talus, and then removing the navicular Although the arch still stands, it will bear little weight, the third cuneiform being inadequately supported behind but with the navicular and the talus retained the arch is a good one "[0]

8 The axis of standing (Fig. 3 A) accordingly extends in a line from the medial calcaneal tubercle to the head of the third metatarsal Counterbalancing takes place over the remaining metatarsal heads, the tubercle at the base of the fifth met and the medial and the lateral arche axis of locomotion (Fig 3 A) is a one It extends in a line from the inferior calcaneal tubercle to the ball great toe It then breaks in final prop to correspond to the line of action sesamoid muscles. (In adults, due universality of a mild hallux valgu line is deflected somewhat laterally)

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12 Functional stability of the first tarsal segment (great toe first meta bone sesamoids medial cuneiform) important factor in restraining pronati the hindfoot.

13 Motions of the tarsal joints in pronation and supination (subtalar and tarsal) abduction and adduction (m sal) plantarflexion and dorsiflexion (tarsal) combinations of these action in torsion, and also independent actic the first metatarsal segment Motion o medial side of the foot is much gr than on the lateral. Here a wide ranş inversion, eversion and plantarflexion is sible Motion on the lateral side is lir largely to axial rotation.

14 Torsion is an important facto

maintaining balance physiologically and in pathologic conditions When the hindfoot is pronated the forefoot undergoes compensatory supination, else it would dig into the ground. Conversely when the hindfoot is supinated (as in cavus) the forefoot undergoes pronation in order to reach the ground (Fig. 8 A and B)

15 The peroneus longus (Fig 6 A) is of key importance in normal locomotion. It is the only muscle which forcefully plantarflexes the medial half of the foot against the ground. In its action the forefoot is pronated, narrowed and abducted The first metatarsal head is plantarflexed to about 2½ cm. lower than the adjoining heads There is a corresponding shortening of the foot and heightening of the medial arch The first metatarsal head slightly opposes and underrides the second (Fig. 9 A D) The action of plantarflexion takes place diminishingly in the following joints first metatarsocuneiform, 1 to 1½ cm. medial cuneifonavicular 1 cm naviculotalar negligible.

16 The calf muscle group forcefully plantarflexes against the ground the lateral half of the foot only (no such action on the medial half) It is a plantarflexor supinator (Fig 9 E) The combined action of the peroneus longus and the calf muscles results in direct plantarflexion (Fig 9 F)

17 The sesamoid muscles (abductor hallucis adductors transversus and obliquus flexor brevis hallucis—2 heads (Fig 20 A) plantarflex with force the proximal phalanx of the great toe and (by elongation of the extensor tendon) extend the distal phalanx These muscles provide the main final thrusting power in propulsion.

18 The flexor longus hallucis plantarflexes the terminal phalanx as the great toe is about to clear the ground.

19 In the maintenance of equilibrium the weight center of the body constantly is shifting above the area of ground support in both the frontal and the sagittal planes. In fatigue tests performed at the University of Southern California, it was found that



Fig 9 Illustrates action of peroneus longus as plantar flexor abductor pronator of forefoot. This is the only muscle that forcefully plantar flexes the medial half of the forefoot. (A) Lateral view Note prominence of ball of great toe and of tendon of peroneus longus above ankle (B) Dorsal view Foot in eversion forefoot pronated in relation to hindfoot. (C) Medial view Arch heightens correspondingly to flexion of forefoot. (D) Plantar view Creases indicative of flexion, pronation and narrowing of forefoot slight opposing and underriding of first metatarsal head in relation to second. (E) Calf action plantar flexor adductor supinator This muscle forcefully plantar flexes the lateral half of the foot only (F) Combined action of calf and peroneus longus muscles Direct plantar flexion (Photos A to D from Duchenne, G B Physiology of Motion, 1867 English Edition, translated by E. B Kaplan, Philadelphia, Lippincott)

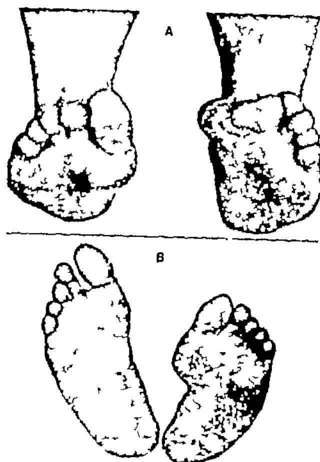


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8 The axis of standing (Fig 3 A) accordingly extends in a line from the medial calcaneal tubercle to the head of the third metatarsal Counterbalancing takes place over the remaining metatarsal heads the tubercle at the base of the fifth metatarsal and the medial and the lateral arches. The axis of locomotion (Fig 3 A) is a broken one It extends in a line from the lateral inferior calcaneal tubercle to the ball of the great toe It then breaks in final propulsion, to correspond to the line of action of the sesamoid muscles. (In adults due to the universality of a mild hallux valgus this line is deflected somewhat laterally)

9 The tuberosity at the base of the fifth metatarsal acts as an auxiliary intermediate pier for the lateral arch (Fig. 6 B) It affords great comfort in both stance and locomotion. It also forms the inferolateral wall of the peroneal groove (Fig. 6 C) In addition, it provides a fulcrum to facilitate the action of the peroneus longus in switching the body weight across the foot to the ball of the great toe

10 The metatarsal heads arch only when the toes are flexed (Fig 7 A and B) On tiptoe the body weight is borne on the bases of the proximal phalanges of the outer 4 toes (Fig 7 C) and on the advanced sesamoids of the great toe (Fig. 7 D)

11 The sesamoid bones move in whichever direction the great toe moves (Fig 7 D) They act as a self adjusting anterior pier Thus they maintain stability of the great toe in its varying positions of function.

12 Functional stability of the first metatarsal segment (great toe, first metatarsal bone sesamoids, medial cuneiform) is an important factor in restraining pronation of the hindfoot.

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Fig 9 Illustrates action of peroneus longus as plantar flexor abductor pronator of forefoot. This is the only muscle that forcefully plantar flexes the medial half of the forefoot. (A) Lateral view Note prominence of ball of great toe and of tendon of peroneus longus above ankle (B) Dorsal view Foot in eversion forefoot pronated in relation to hindfoot. (C) Medial view Arch heightens correspondingly to flexion of forefoot. (D) Plantar view Creases indicative of flexion, pronation and narrowing of forefoot slight opposing and underriding of first metatarsal head in relation to second. (E) Calf action plantar flexor adductor supinator This muscle forcefully plantar flexes the lateral half of the foot only (F) Combined action of calf and peroneus longus muscles Direct plantar flexion. (Photos A to D from Duchenne G B Physiology of Motion 1867 English Edition, translated by E. B Kaplan Philadelphia, Lippincott)

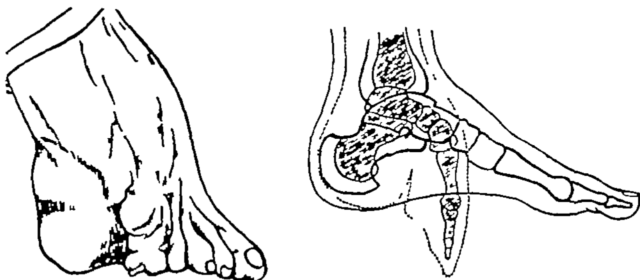


FIG 10 (*Left*) Chinese Mandarin s foot The deforming effect of long-continued externally applied force (binding) is illustrated. These feet are small and practically useless (*Right*) Drawing of a natural foot showing the bones and a corresponding *section of a Chinese deformed foot. The outline of the latter is dotted, and the bones* are shaded

young men in perfect physical condition would collapse under the strain of standing in one position without moving for 20 to 45 minutes

20 The powerful inferior calcaneocuboid (long plantar) ligament (Fig 6 D) by virtue of its firm attachments to the lateral cuneiform and the outer two metatarsals strongly resists the upward motion of the outer tarsal bones when the foot is plantar flexed forcefully against the ground by the calf muscles Its integrity is indispensable in maintaining the stability of the essential arch There is no similar restraining ligament on the medial side of the foot.

21 The foot is readily susceptible to the deforming influence of long-continued externally applied force This is exemplified best in the extreme deformity of the Chinese mandarin s foot which results from deliberate binding (Fig. 10 A and B) and also in the universality of varying degrees of hallux valgus resulting from pointed toed shoes This principle also has therapeutic application as in the correction of clubfeet by wedging of plaster casts

22 On flexion of the knee, the out toeing diminishes. The leg straightens in relation to the great toe to improve the leverage of gait.

BIOMECHANICAL CONSIDERATIONS

The forces of locomotion converge to the ball of the great toe (Fig. 11 A and B) preparatory for the final thrust from the ground The action is a spiral one (Fig 9 A and D) in an oblique axis commencing at the lateral inferior calcaneal tubercle (Fig 3 A and C)

Action is initiated as the heel of the forward extended leg contacts the ground on its posterolateral aspect (the surface between the inferior calcaneal tubercles) With propulsive power supplied by the opposite leg, the body weight rolls forward until the entire foot is brought to the ground. The weight line now extends perpendicularly to its center The body weight at this stage is borne chiefly by the lateral arch, with countersupport from the medial arch

As the action continues the peroneus longus muscle with fulcrumage provided by the tubercle at the base of the fifth metatarsal switches the weight medially to the ball of the great toe Now the weight is assumed by

the medial arch The transtarsal action is made possible by the pivotal action of the essential arch. The third metatarsal heads acts as the pivotal center This transtarsal transfer is facilitated by the arching of the meta tarsal heads as the body weight progresses along the bases of the proximal phalanges assisted by the action of the toes

The toes now "dig in" to supply a fixed point. With the foot directed forward by the combined action of the calf and the peroneus longus muscles, the sesamoid muscles contract energetically to thrust the body forward for the final 'take-off" from the ground The flexor longus hallucis assists by flexing the terminal phalanx as the foot is about to clear the ground.

In standing, the weight is balanced over the pivotal axis of the essential arch. It is borne predominantly by the lateral arch The medial arch affords counterbalance

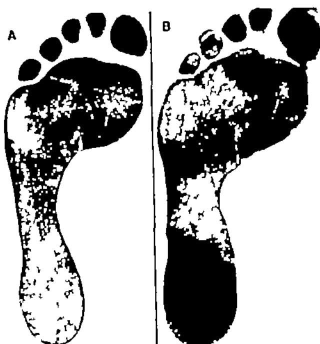


Fig 11 (A) Normal footprint, standing (B) Same in locomotion Forces concentrate toward great toe Note impression of proximal phalanx. (After Munson)

CRITICAL ANALYSIS OF THE CONVENTIONAL SHOE

Comfort, maximum efficiency and preservation of function of the foot from the biomechanical point of view are dependent upon the normal progression the distribution and the dissipation of its dynamic forces

In order not to interfere with these forces the shoe must be in balance with the skeletal bearing structures of the foot. In addition it must dynamically accommodate and synchronize with its actions

The conventional shoe fails in many respects to fulfill these basic requirements On critical analysis at least 8 major faulty factors in its design can be identified each of which independently causes distortion of the normal course of the streams of force across the foot The pattern of the distortion resulting from each of these is quite similar The streams are diverted and largely dissipated lateralward along the outer side of the foot. Then the residual forces are shunted to the medial and distal aspects of the great toe finally to be spent as a distorted take-off thrust from the ground The ball of the great toe (the anterior heel") is bypassed.

The correction of each of these 8 factors is vital to favor the normal harmonious action of the foot, the chain being no stronger than its weakest link. These distorting factors of the conventional shoe are as follows

1 Its longitudinal axis does not correspond to that of the foot.

2. Its heel does not dynamically accommodate the lateral rolling action of the foot in the initiation of gait.

3 Its shank section is not balanced with the foot in its transverse axis

4 Its shank does not accommodate the dynamic demands of the foot.

5 Its metatarsal floor does not conform to or dynamically accommodate the foot.

6 The peak of the curve of its arch (also of the commercial arch support) is too far forward and too high. Its curve does not conform to the configuration of the foot.

7 Its great-toe section is malaligned with that of the foot in its longitudinal, horizontal and vertical axes.

8 Its heel section design substitutes an opposing pivotal action over a posteriorly extended fulcrum for the normal "rocker" action of the heel of the unshod foot.

1 **Its Longitudinal Axis Does Not Correspond to That of the Foot.** The conventional shoe is constructed in an arbitrary longitudinal axis of symmetry (Fig 12 B) The axis of the foot is asymmetrical (Figs 3 A, 12 A) The heel and the shank regions are located eccentrically in relation to the forefoot. The vertical axis of the calcaneus, because of the eccentric location of this bone is offset lateralward about 1 to 1½ cm from that of the tibia (Fig 3 B)

A line drawn from the inferior medial calcaneal tubercle through the third metatarsal head inclines normally toward the ball of the great toe (Fig. 3 A) It passes forward between the second and the third toes This line also represents the axis of balance (standing) as well as the direction of the essential arch The medial inclination of this line favors the transfer of the forces of locomotion toward the great toe

A similar line drawn from the center of the heel of the conventional shoe (which inflares in relation to the foot because of its axis of symmetry) through a point on its sole corresponding to the third metatarsal head inclines away from the ball of the great toe It passes forward through the region of outer toes (Fig 12 D) The effect on the foot of this medial inflaring of the axis of the heel section of the shoe is a deflection of the streams of force lateralward toward the outer toes. The ball of the great toe is bypassed (Fig. 13 A and B) The heel section of the shoe, together with its counter, acts as a misdirecting rudder

The distorted forces are largely dissipated along the outer toes and the metatarsal region. Then the residual forces are retardedly shunted to the medial and the distal margins of the great toe finally to be spent in a distorted take-off from the ground.

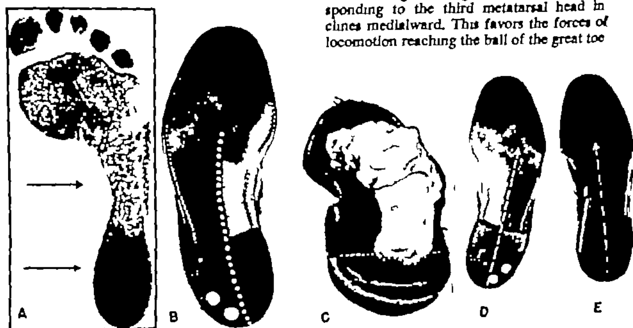


FIG 12. (A) The bearing surface of the posterior two thirds of the foot is offset lateralward in line with the lateral toes. (B) Inflaring (because of its construction in the axis of symmetry) hind section of the conventional shoe acts as a rudder to misdirect the forepart of the encased foot lateralward. The forces of locomotion, being correspondingly distorted bypass the ball of the great toe (Fig. 13 A, B) (C) The foot crowds the lateral margin of the conventional shoe the medial margin is redundant. (D) A line drawn from the center of the heel of a conventional shoe and passing through the sole at a point corresponding to the third metatarsal head inclines away *from the great toe and passes through the region of the outer toes.* (E) Physiologic shoe A line drawn from the center of the heel through the region of the sole corresponding to the third metatarsal head inclines medialward. This favors the forces of locomotion reaching the ball of the great toe

A

B

FIG 13 (A) The markings on the inner and the outer surfaces of the malaligned conventional shoe reflect the bypassing of the ball of the great toe by the forces of locomotion. (B) The irregular wear of the shoe reflects its unbalanced relationship with the action of the foot.

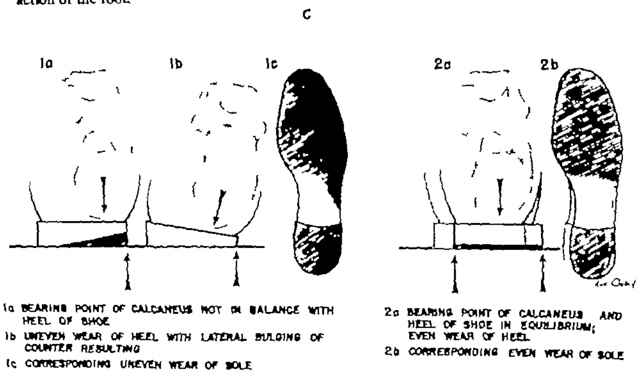


FIG 13 C (1a) Bearing point of calcaneus not in balance with heel of shoe (1b) Uneven wear of heel with lateral bulging of counter resulting. (1c) Corresponding uneven wear of sole (2a) Bearing point of calcaneus and heel of shoe in equilibrium even wear of heel. (2b) Corresponding even wear of sole

The long axis of the conventional shoe thus crowds the foot lateralward along the entire length of the shoe (Fig 12 C) This is reflected in the shoe in the premature wearing-off of its heel as well as of its sole (Fig 13 C) The misdirected secondary forces acting on the inner margin of the great toe favor the development of hallux valgus secondary metatarsal breakdown and also ingrown toenails

2. **Its Heel Does Not Dynamically Accommodate the Lateral Rolling Action of the Foot in the Initiation of Gait.** The manner in which the gait is initiated determines the course of the entire journey of the streams of force across the foot Once distorted from their normal channels these streams fail to regain it. Therefore the manner in which the heel of the shoe takes the ground is of primary importance

In the initiation of gait, the heel of the forward extended leg rolls posterolaterally on the arched surface between the medial and the lateral inferior calcaneal tubercles (Fig. 3 C) The vertical axis of weight bearing of the calcaneus shifts correspondingly The conventional shoe fails to make provision for this action

This lack of accommodation is reflected in the shoe by a rapidly developing bulging of the counter and premature, irregular "wearing down" of the outer margin of the heel (Fig. 14 A) as well as of the sole (Fig. 13 C)

The resulting supination of the backfoot is one of the principal evils of the conventional shoe

3 **Its Shank Section Is Not Balanced With the Foot in its Transverse Axis.** The shank section of the foot is of utmost importance in the biomechanics of the foot. It is here that the shifting from the axis of balance (standing) to that of locomotion takes place The shank also serves in a similar capacity in the side-to-side swaying of the body incident to the maintenance of vertical equilibrium. It provides in the form of the tubercle of the fifth metatarsal an auxiliary intermediate pier (Fig 6 B) This adds greatly to comfort in locomotion

This tubercle forms the inferolateral wall

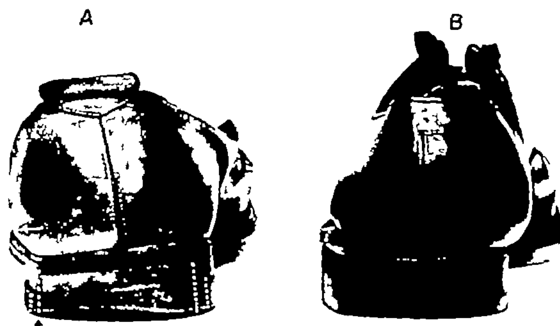


FIG 14 (A) Heel of conventional shoe lacks accommodation for the lateral shift of the vertical axis of weight-bearing of the calcaneus in the initiation of gait. (B) The heel is dynamically accommodated. The posterior half of its lateral margin is extended a distance equal to the lateral shift of the vertical axis of weight-bearing.

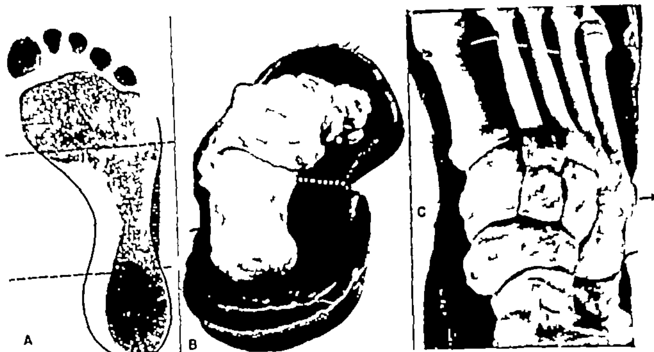


FIG 15 (A) Outline of the sole of a conventional shoe showing lateral inadequacy and medial redundancy of shank area. (B) Shank section is redundant medially (C) The lateral margin of the foot overrides the shoe The tubercle at the base of the fifth metatarsal loses its important mechanical advantage

of the peroneal groove (Fig 6 C) It acts as a fulcrum to facilitate the transfer of the body weight by this muscle across the foot to the ball of the great toe.

Due to the faulty longitudinal axis as well as to the faulty outline of the outer sole of the conventional shoe the lateral margin of its shank is inadequate (Fig 15 A and C) while the medial margin is redundant (Fig 15 A and B)

The foot, particularly the tubercle at the base of its fifth metatarsal, overrides the lateral margin of the shoe (Fig. 15 C) The resulting loss of support for this tubercle places the peroneus longus muscle at a great mechanical disadvantage in the fulfillment of its important function of transferring the body weight to the ball of the great toe

The medial redundancy of the shank acts to retard and distort the pronatory action of the peroneus longus

Incidentally the correction of this imbalance allows a more snug fit of the arch section of the shoe It improves the relationship of the first metatarsal bone to the great toe by lessening its tendency to varus It also serves to protect the ball of this toe from medial crowding and friction against the shoe

4 **Its Shank Does Not Accommodate the Dynamic Demands of the Foot.** The major functions of the foot are biaxial. The axis of locomotion is entirely different from that of standing (Fig 3 A) The form of the foot changes radically in locomotion (Fig 9 A D)

The axis of standing extends from the inferior medial calcaneal tubercle to the third metatarsal head. The main axis of locomotion extends from the lateral inferior calcaneal tubercle to the ball of the great toe

The action of the shank section of the foot in locomotion is powered by the peroneus longus muscle and is predominantly a torsional one The foot in this spiral action is pronated and narrowed The ball of the great toe is plantarflexed to about 2 cm in relation to the adjoining metatarsal heads. There is a corresponding shortening of the foot and heightening of the medial arch (Fig 9 A-C)

The conventional shoe provides only a

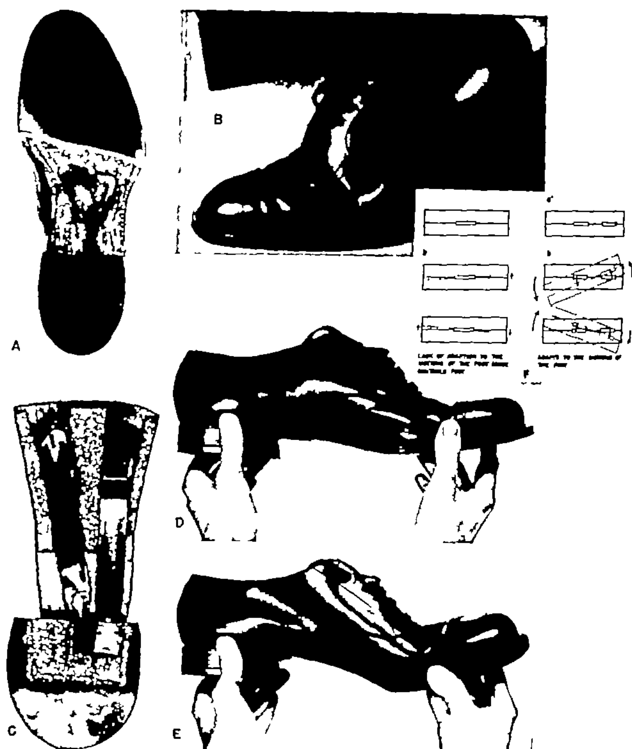


FIG 16 (A) Example of a rigid shank reinforcement of a conventional shoe (single arbitrary axis) unadaptable to the normal axis of propulsion. (B) Same in action Shoe is forced to break lateralward. The forces of locomotion are distorted correspondingly (C) Physiologic shank reinforcement Anchored at their bases by means of suitably adapted joints. These are designed to allow the shoe to simulate the natural action of the foot. (D E) Same in action Dynamically accommodates the spiral action of the foot in locomotion (F a, b c) Illustrates diagrammatically the lack of adaptability and the spreading force induced between layers of shank by the conventional shank reinforcement (a b c) Adaptability of a physiologic shank reinforcement to the spiral action of the foot in locomotion.

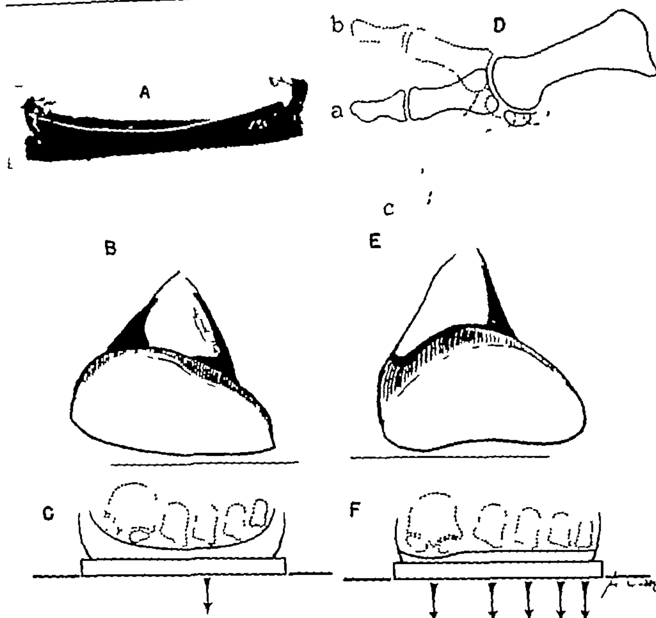
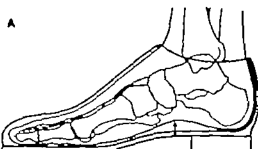


FIG. 17 (A) C S metatarsal bed of conventional shoe Note "boat-bottom" concavity (B) Corresponding configuration of the conventional last (C) Concentration of force region of third metatarsal head. Ball of great toe rests on an inclined plane (D) Sesamoid bones move with the great toe (a) sesamoids in neutral position (b) toe extended, sesamoids advance (c) toe in flexion sesamoids recede. (E) C S physiologically adapted last. (F) Modified metatarsal bed sesamoids recessed weight distributed evenly

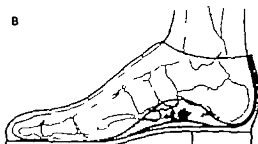
single rigid (and arbitrary) longitudinal axis (Fig 16 A) This cannot possibly accommodate the dynamic demands of the two diverse major axes of function (Figs 3 A 16 F) The foot is compelled to function, both in standing and in locomotion, in this single arbitrary axis The shoe in locomotion, cannot "break" other than laterally and distalward (Fig. 16 B) instead of behind the ball of the great toe as is necessary to accommodate the normal action of the foot (Figs 9 A D, 11 A and B 16 D and E)

Thus the forces of locomotion are directed contrariwise to the action of the foot. After being largely dissipated lateralward, they are shunted circuitously to the medial and the distal margins of the great toe.

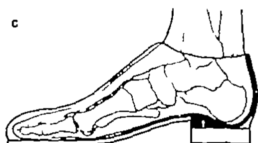
There seem to be two schools of thought regarding the preference for a rigid shank (for support) or for a flexible shank (for dynamic accommodation) It appears obvious that an ideal shank reinforcement is



LOCATION OF PEAK OF SHOE ARCH DOES NOT CORRESPOND TO ANATOMIC PEAK, (TOO HIGH AND TOO FAR FORWARD).



PEAK OF DETACHED ARCH SUPPORT IS IN SIMILAR UNBALANCED RELATIONSHIP TO FOOT NOTE IMPINGEMENT AGAINST NAVICULAR TUBERCLE



LOCATION OF PEAK OF SHOE ARCH CORRESPONDS TO ANATOMIC PEAK. NOTE FORMATION OF WEDGED RECESS IN HEEL.

FIG 18 (A) Note incongruous rela tionship of floor of conventional shoe with arch section of foot. (B) Same reflected in conventional "arch support" shoe (C) Physiologic arch section of shoe "Wedged" recess for heel inclines lateral ward, downward and forward to conform to peak of lateral arch

one which would provide both support for the longitudinal arch as well as adaptability *to the dynamic demands of the foot*

This is achieved by the mobilization of the anchorage of its reinforcing blades by means of suitably adapted joints (Fig 16 C) Dual blades with joints designed to simulate the diversity of action of the medial and the lateral sides of the foot are preferred (The medial half of the foot can be in verted or everted over a wide range The action of the lateral half is predominantly one of axial rotation)

A self adjusting shank of this type has an added advantage in that it compensates to a large degree for the normal variations in the toe-ball and the ball-heel relationships in feet of identical length.

5 **Its Metatarsal Floor Does Not Conform to or Dynamically Accommodate the Foot.** The metatarsal floor of the conventional shoe is shaped in the form of a boat bottom" concavity (Fig 17 A-C) This is due primarily to the faulty configuration of the last (Fig. 17 B) It is accentuated by the inadequacy of the filling material used to level the inner surface of the shoe to correct the effects of the last and the in-tucked upper (Fig. 17 A)

The metatarsal region of the foot arches only when the toes are flexed, as shown by Harris et al (Fig 7 A and B) In locomo*tion as pointed out by Duchenne (Fig. 9* A and C) the ball of the great toe is plantarflexed in relation to the adjoining metatarsal heads The location of the sesamoid bones shifts corresponding to the action of the great toe (Fig 17 D)

The concave metatarsal floor of the conventional shoe fails to accommodate these diverse actions Instead it invites a concentration of force on the third metatarsal head, this being the site of greatest de pendency (Fig 17 C) The ball of the great toe lies on the inclined margin The forces of locomotion intended for the ball of the great toe are distorted along circuitous channels similar to those previously referred to the ball of the great toe is bypassed.

6 **The Peak of its Arch (Commercial Arch) is too Far Forward and too High.** *Its curve does not conform* to the configura tion of the inner arch which has its peak immediately proximal to the talonavicular junction (Figs. 2 A and B 9 C) The corresponding location of this peak in the shoe is within its heel section (Fig 18 C)

The angulation of the calcaneus forms the peak of the arch (Fig 2 A and B) The

foot anterior to this point of angulation is relatively flat (Fig 2 A) The arch thus formed is asymmetrical, having a very short posterior pillar and a long anterior one The conventional shoe is constructed as if the arch were symmetrical (Fig 18 A and B) There fore its heel section is relatively flat, while its peak is too far forward and high (Figs 18 A 19 A) This acts as a supinatory unbalancing force on the forefoot It favors the development of secondary compensatory pronation of the calcaneus and eversion of the great toe The forces of locomotion are distorted lateralward along the usual circu itous channels common to all supinatory unbalancing factors

The congruity of outline established by the correction of this imbalance provides within the heel area a cuplike medially wedged recess (Fig 18 C) This wedge con struction acts to support the posterior pillar of the arch against calcaneal pronation A support at this site has the advantage in that it does not produce supinatory im balance as does the conventionally placed wedge under the medial margin of the heel

There are additional advantages of the balanced configuration of the arch. It oblit erates the dead" space between the shoe and the foot. It also tends to prevent the foot from sliding forward within the shoe.

7 Its Great Toe Section is Mala ligned With That of the Foot in its Longitudinal Horizontal and Vertical Axes. The preservation of function of the great toe embodying the entire first meta tarsal segment, is of paramount importance in foot function. The stability the firmness and the springiness of gait, in addition to the satisfactory final thrust from the ground, are dependent upon its integrity

The conventional shoe is constructed as if the great toe were located in the *center of* the foot (Fig 20 C) As a result, the great toe and the sesamoid muscles are deflected correspondingly (Fig. 20 B) This force augmented by the upcurved *margin* of the innersole (Fig. 20 D and E) as well as the low and sloping toe box (Fig. 20 D) favors the

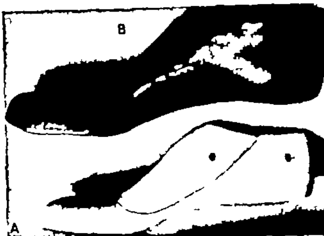


Fig 19 (A *Bottom*) Conventional last, posterior half lower surface practi cally flat. (B *Top*) Physiologic last, con forms to configuration of foot Posterior pillar of longitudinal arch is supported inferomedially by its design

formation of hallux valgus secondary meta tarsal breakdown and also ingrown toenails.

However the centrally pointed toe is not the only or even the greatest of the distort ing factors of the conventional shoe which find expression in this type of deformity and breadown

All of the numerous other factors that distort the streams of locomotion lateral ward lead to the shunting of these forces to the medial and the distal margins of the great toe. These are at least equally re sponsible for the foregoing conditions

The inner line of the toe section of the shoe whether it be inflared straight or de flected lateralward, has in itself no great significance It is only in its *relationship to* the longitudinal axis of the hind section of the shoe that it assumes any considerable importance

With the inflaring *hind section* of the shoe pointing the foot lateralward (as is the case in the conventional shoe because of its axis of symmetry) the centrally pointed toe section is not so severely malaligned with *the foot* as it may appear at first. (The foot is rotated in a similar manner within the shoe by both of these factors)

In view of *this* the added space provided by a "straight inner line" or "add*uctor*" type

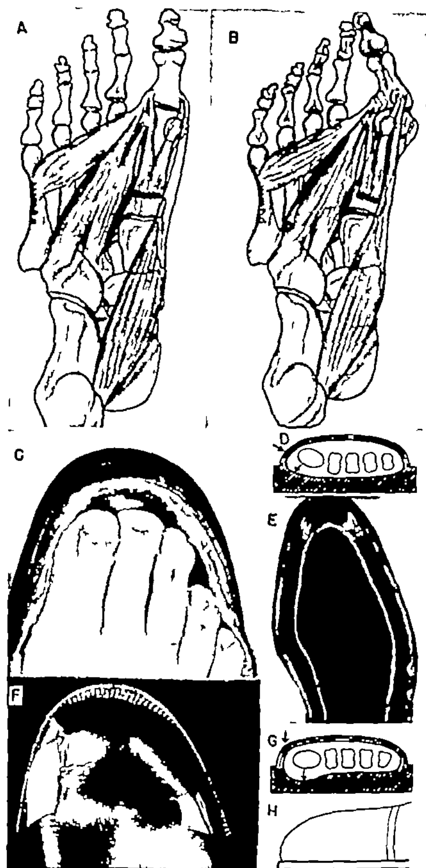


FIG 20 (A) Normal sesamoid muscles. (B) Deflection of the sesamoid muscles by the conventional shoe. (C) The conventional shoe is designed as though the great toe were located in the center of the foot. (D E) The diminished base line, resulting from the upcurved margin of innersole and the sloping of the toe box contribute to the deforming force of the malaligned toe section of the shoe (F) With coaxial alignment of hind foot, a relatively slight added accommodation is all that is necessary to coalign the shoe with great toe (G H) The toe section of the shoe is coaligned with the foot. The medial sloping is eliminated The sole is recessed to accommodate the action of the great toe (Photos A and B from Stein, H C. Hallux Valgus, Surg., Gynec. & Obst. 66 889-898)

of shoe per se would be of little significance and of limited utility

With the axis of the hind section of the shoe co-aligned with the axis of balance the point of the shoe can be brought to correspond to that of the great toe with but slight modification and with relatively little change in the external appearance of the shoe from that of the conventional The alignment of the shoe with the great toe is determined best by the relationship of its inner toe line to the longitudinal axis of the shaft of the first metatarsal bone rather than to the expanded head of this bone

8 **Its Heel Section Design Substitutes an Opposing Pivotal Action Over a Posteriorly Extended Fulcrum for the Normal "Rocker" Action of the Foot** The bony as well as the soft tissue configuration of the foot is rounded (Figs 2 B 9 C) In dorsiflexion of the unshod foot against the ground the heel revolves rocker

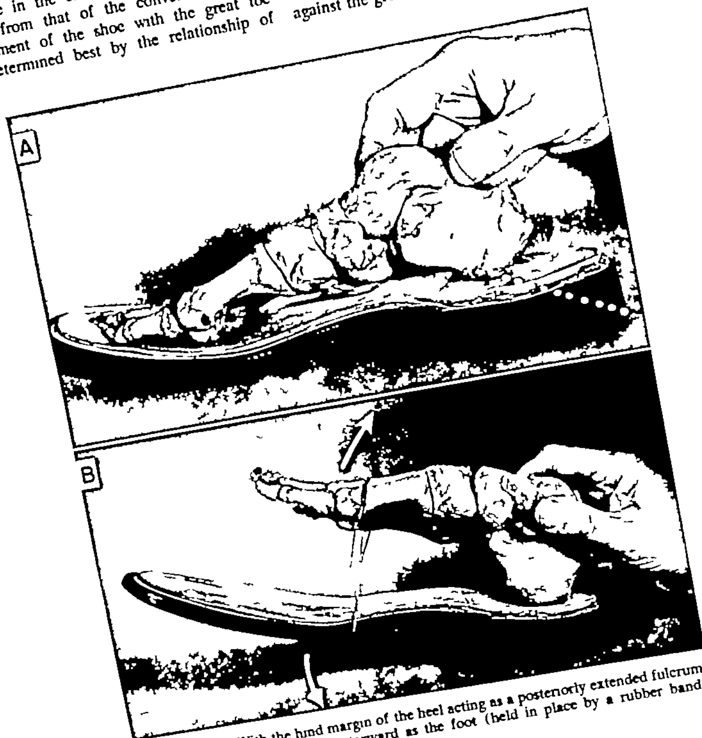


FIG 21 (A) With the hind margin of the heel acting as a posteriorly extended fulcrum the conventional shoe goes plantarward as the foot (held in place by a rubber band) is dorsiflexed against the ground (Fig 21 B)

like on an underlying rotating fulcrum on the intertubercular surface of the calcaneus (Figs 2 B and 3 C) This action is smooth, and unopposed and is performed with a minimum of energy

With the foot encased in a conventional shoe this normal rocker action is substituted by a pivotal action over a posteriorly extended lever (Fig 21 A) The lower hind margin of the external heel acts as the fulcrum The distance between it and the contact point of the inferior calcaneal tubercle represents the lever (Figs 21 A 23 A)

Because of this faulty mechanical relationship with the foot, the sole of the shoe is thrust plantarward each time the foot is actively dorsiflexed against the ground (Figs 21 B 23 B) Although the shoe may be laced firmly this spreading force exists Considering that the average person takes 14 080 steps daily the expenditure of extra energy because of this feature of the conventional shoe is tremendous This deleterious influence may be substantially lessened by the interruption of the rigidity of the above leverage action

The jointed anchorage of the shank reinforcement previously described (Fig. 16 C) has this effect on the anterior lever arm It affords some rocker action to the heel.

This action is augmented by the interruption of the rigidity of the hind lever This is accomplished by means of clefting the peripheral margin of the heel (Fig. 22 inset) The action, to be most effective, must extend throughout the full thickness of the heel section into the shoe (Fig. 22) Thus the heel is divided into central acting and peripheral acting sections The body weight rocks over the central section (c) The peripheral section (p) provides stability and surface traction. This multiple action principle of the heel is not applicable to high heeled shoes Here the vertical line

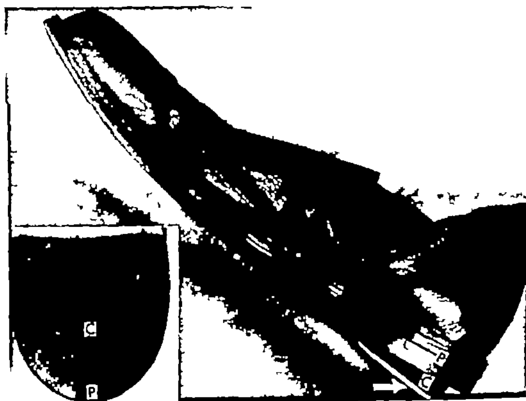


FIG 22 A type of clefting to restore normal rocker action to heel (inset) The action may be minimal However it must extend to within the shoe The "central heel" (c) acts predominantly in locomotion the "peripheral heel" (p) affords a broader more stable base in standing as well as improved traction in locomotion

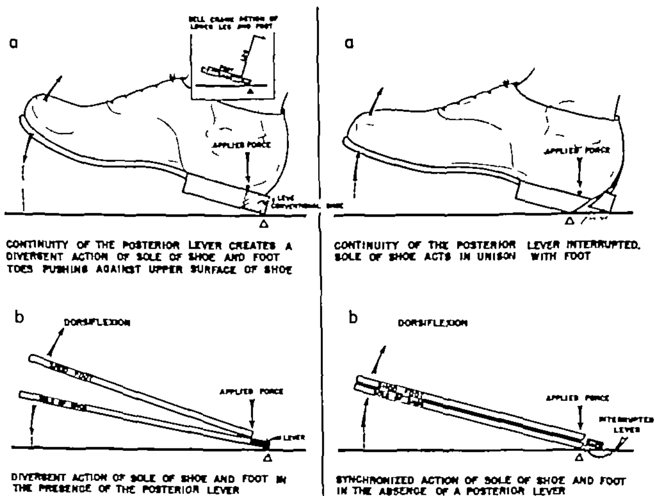


FIG 23 Diagrammatic illustration of the contrasting actions of conventional and physiologic heel sections.

of equilibrium is advanced toward the center of the foot and walking takes place in equinus.

PROJECTED MODIFICATIONS

1 Axis. The section of the shoe posterior to the region of the metatarsal floor is transposed lateralward a distance equal to the eccentricity of the vertical axis of the calcaneus (Figs 3 B 12 E) With this *modification, a line drawn from the center* of its heel to a point on its sole correspond ing to the third metatarsal head will incline toward the ball of the great toe and pass between the second and the third toes (Fig. 12 E)

2. External Heel. The posterolateral section of the heel is shifted and extended lateralward to accommodate the correspond ing shifting of the vertical axis of weight bearing (Figs 3 C 14 B) in the initiation of gait.

3 Shank and Balance. The last is extended lateralward sufficiently to provide an adequate base for the tubercle of the fifth metatarsal. The medial redundancy is pared The relationship of the outer sole is modified correspondingly (Fig. 12 E)

4. Shank and Mobilization The shank reinforcement (see foregoing) is anchored *by means of joints designed to simulate the* natural action of the foot. Dual blades are preferred (Fig 16 C) These are placed to correspond to the two major axes of function. When a single blade is used it corresponds to the axis of balance

5 Metatarsal Floor In order to favor the transfer of the load to the ball of the great toe and to accommodate the action of this toe and its sesamoids, a localized

recess is substituted for the boat bottomed concavity (Fig 17 E and F)

6 **Peak of Arch** The heel section is contoured to conform to the inner arch. A cuplike recess is formed, the peak of which corresponds to the talonavicular junc tion (Figs. 18 C 19 B) its floor medially is fashioned to form a wedge support for the posterior pillar of the arch

7 **Alignment of the Great Toe.** The tip of the shoe is fashioned to correspond to the longitudinal axis of the normal great toe. With the hind section of the shoe aligned coaxially only a slight modification of the external appearance of the shoe from that of the conventional is necessary to ef fect this correction (Fig 20 F) Wood is added to accommodate the action of the toe and to correct the medial sloping of the toe box (Fig 20 G and H)

8 **Mobilization of the Opposing Hind Lever** The mobilization of the shank by means of the jointed shank reinforce ments previously described allows a con siderable degree of "rocker" action of the heel section This is supplemented by inter rupting the continuity of the rigid hind lever by *means of clefting the heel peripherally* (see foregoing) The action involves the full thickness of this section of the shoe (Figs 22 and 23) In this manner a movable center is formed within the heel section itself which allows a rocker action simulating that of the unshod foot.

Numerous variations may be substituted to gain the objectives of each of the fore going modifications There are also various means of camouflaging some of these modifi cations that may be objectionable from the esthetic point of view

SUMMARY AND CONCLUSIONS

1 Civilization has imposed severe penalties on the foot in the form of hard pave ments and rigid confining unbalanced and unsynchronizing shoes This is threatening to convert us gradually into a nation of "foot-cripples

2 Hallus valgus metatarsal breakdown, contracted, deformed toes and a multitude of other foot ailments" and related disorders attributable to the conventional shoe in varying degrees have become almost universal

3 The perfect foot is to be found only in primitives and peoples who do not wear shoes and in very young children before the adverse effects of the conventional shoe have become manifest.

4 Symptomatic foot disorders are prac tically unknown in peoples who do not wear shoes Their feet are well developed, power ful and undeformed

5 The foot is extremely prone to deformity under the influence of long-continued, externally applied, misdirected force

6 The foot, as a rule is very obliging it does not rebel freely Instead, it readily adapts itself to malaligned shoes The shoe actually may be referred to as "feeling very comfortable," even though deteriorative changes of the foot are taking place constantly This is particularly true in persons pursuing sedentary occupations

7 Comfort maximum efficiency and preservation of function of the foot are dependent upon the normal progression distribution and dissipation of its dynamic forces The shoe, in order not to obstruct these forces must be in balance with the skeletal bearing points of the foot and must dynamically accommodate and synchronize with its actions

8 The preservation of function of the foot, including the design of the shoe for the normal foot, is primarily the responsibility of the orthopaedic surgeon.

9 Great advances have been made in our understanding of the biomechanics of the foot. The need for balancing and synchronizing the shoe with the action of the foot to conserve its function has long been recognized In spite of this the design of the shoe still continues to be dictated arbi trarily by custom fashion and the whims of the manufacturer rather than by sound

engineering principles based upon the biomechanics of the foot.

10 Distorted ideas lead to distorted shoes distortion of *foot function and finally* to distortion of foot structure

11 Unlike a sausage the foot is a highly developed member of complex formation, every factor of which needs thoughtful consideration in determining its proper clothing.

12 The calcaneus is offset lateralward in relation to the foot. This architectural *arrangement* adds mobility to the foot at the expense of stability Otherwise muscle action would be impossible It favors the direction of the forces of locomotion toward the great toe. It enables the foot to function biaxially

13 The essential arch is formed by the calcaneus the cuboid lateral cuneiform and the third metatarsal bones held together firmly by the powerful long plantar ligament. This is the only combination of bones that will stand up alone as an arch It will bear little weight, but with the talus and the navicular added, the arch is a good one

14 Foot function is predominantly bi axial. The axis of standing extends in a line from the medial calcaneal tubercle to the third metatarsal head. The axis of locomotion extends from the lateral inferior calcaneal tubercle to the ball of the great toe.

15 The axis of pivotal rotation in shifting from the standing to the walking position, corresponds to that of the essential arch (This also constitutes the axis of standing or balance) The third metatarsal head acts as the pivotal center

16 The peroneus longus is the chief muscle involved in this shift. It is the only muscle that plantarflexes with force the medial half of the foot (the calf muscles act only on the lateral half of the foot as a plantar flexor supinator)

17 Impaired activity of the *peroneus* longus *from* any *cause* even *unyielding* shoes favors supination of the forefoot with compensatory pronation of the calcaneus as well as eversion of the great toe

18 The foot in locomotion assumes a radical change in its form The action is a spiral one It is associated with pronation narrowing and abduction of the forefoot and plantarflexion of the ball of the great toe

19 The conventional shoe (which we have learned to accept with a sort of hopeless and fateful resignation) on critical analysis reveals 8 major factors which obstruct the normal progression distribution and dissipation of the dynamic forces of the foot. They all, very much in common tend in locomotion to divert and dissipate the body weight largely toward the lateral half of the foot. Then the residual forces are shunted obliquely (the third metatarsal head acting as a pivot) to the medial and the distal margins of the great toe, bypassing its ball It is almost the equivalent of a functional amputation of the great and the adjoining toes The ball of the small toe is no substitute for that of the great toe Each of these 8 factors requires careful consideration in the design of a physiologic shoe

20 Prior to the Civil War period, right and left shoes were made on identical symmetrical lasts *The shoes were interchangeable on* either foot. When "rights" and "lefts" were first given to the soldiers they were considered objects of derision and ridicule because they were not interchangeable This *marked* the beginning of the application of biomechanical principles to the design of the shoe There have been very few outstanding modifications of its basic *design since* The shoe historically adheres tenaciously to old forms

21 The shoe can be no better *than the* last. Therefore it is important that the last resemble *the foot* and not the reverse Other *factors besides the last* which concern the *shoe itself* are of equal importance in the *design of* a physiologic shoe

22 Some of the more pertinent historical, *anthropologic anatomic* physiologic *and biomechanical* factors that govern or have *important* bearing on the relationship *of the* shoe to the action of the foot have been reviewed. A modification of our pres-

ent concept of the biomechanics of the foot has been presented.

23 The postulates and the details of a projected "correct" rather than "corrective" shoe designed to establish balance dynamic accommodation and synchronization with the action of the foot have been outlined.

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BIBLIOGRAPHY

1 Böhler Lorenz The Treatment of Fractures, Eng ed. 4 Trans. by E. W H Groves, Baltimore Wood 1935

2 Born W The Development of Footwear Ciba Review vol. 34 Basle 1940

3 Bradford, E. H and Lovett, R. W Orthopedic Surgery ed 5 Baltimore Wood 1915

4 Dickson F D., and Diveley R L. Functional Disorders of the Foot, ed 3 Philadelphia, Lippincott, 1953

5 Diveley R L. Foot imbalance J A. M A. 103 1510 1934

——— Orthopedic Appliance Atlas, vol. 4 pp 439-478 Ann Arbor Mich Edwards 1952

6 Duchenne, G B Physiology of Motion 1867 Eng ed. trans and ed. by E. B Kaplan Philadelphia, Lippincott, 1949

7 Elftman Herbert A cinematic study of the distribution of pressure in the human foot, Anat. Rec. 59 481 1934

8 Ellis, T S The Human Foot Its Form and Structure Functions and Clothing, p 114 London Churchill 1889

9 Greig T W Ladies Old Fashioned Shoes, Glencaire Edinburgh, David Douglas, 1885

10 Hall J S. Book of Feet, A History of Boots and Shoes W H Graham, 1847

11 Harris R. I and Beath Thomas Report 1574 Army Foot Survey Ottawa, Nat. Research Council of Canada, 1947

——— The short first metatarsal, J Bone & Joint Surg 31A 553 1949

12 Hauser E. D W Diseases of the Foot, ed. 2 Philadelphia, Saunders, 1950

13 Hiss, J M Functional Foot Disorders, ed. 3 Los Angeles, Oxford Press, 1949

14 Hoffmann, P Conclusions drawn from a comparative study of the feet of barefooted and shoe wearing peoples, Am J Orthop Surg. 3 105 1905

15 Jones, Sir Robert Claw foot, Brit. M J 1 749 1916

——— Military Orthopedics, New York Hoeber 1918

16 Jones, Sir Robert, and Lovett, R. W Orthopedic Surgery ed. 2, Baltimore Wood, 1933

17 Keith A. Engines of the Human Body Am. ed., Philadelphia Lippincott, 1933

——— Man's posture (Hunterian Lectures) Brit M J 1 451 499 545 587 624 669 1923

18 Kidner F C. The prehallux (accessory scaphoid) in its relation to flat foot, J Bone & Joint Surg 11 831 1929

19 Lake Norman The Foot, ed. 2 Baltimore Williams & Wilkins 1939

20 Lewin, Philip The Foot and Ankle, ed. 2, Philadelphia, Lea & Febiger 1941

21 Lovett, R. W New York M J 63.304 1896

22 Lovett, R. W and Reynolds, E. S. A method of determining the position of the center of gravity Am J Physiol. May 1909

23 McBride E. D A conservative operation for bunions J Bone & Joint Surg. 10 735 1928

24 Morton D J The Human Foot, New York Columbia 1935

——— Human Locomotion and Body Form Baltimore Williams & Wilkins, 1952.

——— Mechanism of normal foot and of flat foot, J Bone & Joint Surg 6:368 1924

25 Munson E. L. The Soldier's Foot and the Military Shoe, New York, Banta, 1917

26 Piersol G A Human Anatomy ed. 9 Philadelphia, Lippincott, 1936

27 Quimby H R Pacemakers of Progress, Rumpf Publishing Co 1946

28 Rehman I., Patek, P R., and Gregson M Some of the forces exerted in the normal human gait, Arch Phys. Med 29: 698 1948

29 Roberts P W The initial strain in weak foot, New York M J., August, 1915

30 Schwartz, R. P., Heath, A. L., Misiek, W., and Wright, J N Kinetics of human gait J Bone & Joint Surg 16 343 1934

31 Schwartz, R P., and Heath, A L. Conservative treatment of functional disorders of the feet in the adolescent and the adult J Bone & Joint Surg 31A.501 1949
——— A definition of human locomotion on the basis of measurements, J Bone & Joint Surg 29.203 1947
——— Some factors which influence balance of the foot in walking the stance phase of gait, J Bone & Joint Surg. 19 431 1937

32. Stein, H C. Hallux valgus, Surg., Gynec & Obst. 66 889 1938

33 Steindler Arthur Mechanics of Normal and Pathological Locomotion in Man Springfield, Ill Thomas, 1935
——— Supinatory compensatory torsion of forefoot in pes valgus, J Bone & Joint Surg. 11 272, 1929

34 Thomas, H O Contributions to surgery and medicine Part 8 *In* Fractures, Dislocations, Deformities and Diseases of the Lower Extremities, pp. 6-10 London Lewis, 1890

35 Truslow W Metatarsus primus varus or hallux valgus? J Bone & Joint Surg 7 98 1925

36 Wells, L H The foot of the South African native Am J Phys. Anthropol 15 185 1931

37 Whitman Royal A Treatise on Orthopaedic Surgery ed. 8 Philadelphia, Lea & Febiger 1927

38 Wright Thomas The Romance of the Shoe, Being the History of Shoemaking in All Ages Especially in England and Scotland, C. J Farncombe & Sons, 1922.

13

Coracobrachialis Brevis

Charles O Bechtol, M.D

INTRODUCTION

This paper describes an anatomic variation of the coracobrachialis muscle which may produce painful shoulder This has been found during an operative exploration of a number of shoulders for biceps tendinitis or other surgical lesions In each of these cases definite persistent tenderness was observed preoperatively over the lesser tuberosity of the humerus Surgical correction of the anatomic variation in each case led to a disappearance of the signs and the symptoms in this area.

The coracobrachialis brevis (or superior) muscle is one of the common anatomic variations of the coracobrachialis muscle According to Piersol a study of comparative anatomy shows that in most species the coracobrachialis *has 3 portions, which insert* along the full length of the humerus. In man only the middle of these 3 portions *is commonly present and it is known only* as the coracobrachialis muscle Either the superior or the inferior portion of the *muscle occasionally may be found in man* The coracobrachialis brevis muscle represents an insertion of the coracobrachialis muscle on the upper portion of the shaft of the humerus and sometimes into the lesser tuberosity or the capsule of the joint (Fig. 1) The coracobrachialis muscle when present, presents a mechanical obstruction to the motion of the lesser tuberosity on internal and external rotation of the humerus The degree of mechanical interference is such that it would not necessarily lead to post traumatic changes unless a considerable amount of wear and tear *occurred in this region However once the* lesion is established it is probable that it will be of long duration.

SUBCORACOID BURSA

In most cases, a bursa lies between the coracoid process and the surface of the subscapularis muscle where it attaches to the lesser tuberosity of the humerus. In none of the 3 cases observed was the subcoracoid bursa present. In each case loose areolar gliding tissue was present in this area Due to the repeated trauma, the areolar tissue was thickened, scarred and inflamed. It was evident that the actual painful lesion lay in the traumatized gliding tissue

CLINICAL DIAGNOSIS

The patients present themselves with a *chronically painful shoulder One case* had pain of 3 years duration. On physical examination, pain is experienced on internal and external rotation of the humerus. It may be aggravated by extreme external rotation of the humerus with the arm at the side There is an area of considerable persistent tenderness lying over the lesser tuberosity of the humerus. This can be demonstrated most easily with the humerus in external rotation so as to bring the insertion of the subscapularis muscle out from the cover of the coracoid process. Two of the cases in this series were diagnosed preoperatively The original case was found incidental to an exploration of the biceps

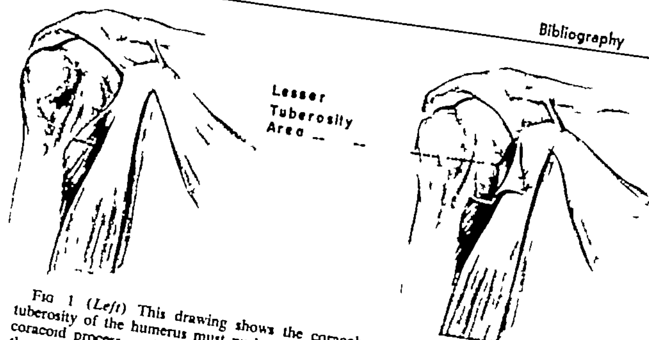


FIG 1 (*Left*) This drawing shows the coracobrachialis brevis muscle The lesser tuberosity of the humerus must push this muscle out of the way as it slides under the coracoid process on internal rotation of the humerus. (*Right*) This drawing indicates the manner in which the muscle was divided and stitched onto the surface of the coracobrachialis muscle to free the lesser tuberosity of the humerus from mechanical interference

tendon. In each case there was an associated peritendinitis of the long head of the biceps There was no indication at operation that the lesion of the coracobrachialis brevis and that of the biceps tendon were dependent upon each other Each lesion evidently is an independent response of the shoulder to repeated trauma

OPERATIVE PROCEDURE

The shoulder is approached through the deltopectoral interval An S-shaped skin incision curved to avoid the axilla, will reduce the tendency to keloid formation which may follow a straight incision Following separation of the deltoid and the pectoralis major muscles the coracoid process is exposed. The coracobrachialis brevis can be seen arising as a fleshy muscle from the coracoid process and from the tendinous portion of the normal coracobrachialis muscle The muscle runs obliquely downward and attaches to the shaft of the humerus and the lesser tuberosity As the humerus is brought into external rotation the marked thickening and inflammation of the gliding tissue overlying the subscapularis muscle can be identified It is probable that some cases will present a thickened bursa rather than merely thickened gliding tissue in this area The definitive treatment consists first of excising the thickened areolar or bursal tissue Then the mechanical obstruction of the abnormal coracobrachialis muscle is corrected Excision of this muscle would leave a raw muscle edge in contact with the surface of the subscapularis muscle To avoid this the coracobrachialis brevis muscle is divided at right angles to its fibers This division is carried out well below the level of the lesser tuberosity Then the muscle is folded back onto the superficial surface of the normal coracobrachialis muscle (Fig. 1) This procedure effectively frees the lesser tuberosity and the subscapularis muscle from further mechanical interference and at the same time presents a surface of undisturbed muscle to the lesser tuberosity Then the wound is closed in the usual manner and the arm is bandaged to the side for a period of 10 days Sutures are removed on the tenth day when active and passive motions of the arm are begun.

BIBLIOGRAPHY

Piersol, G A Human Anatomy ed 9 p 979 Philadelphia, Lippincott, 1936

14

Pain in the Hip Caused by Osteoid Osteoma*

George S Phalen M.D., and David W Patch, M.D †

In 1930 Bergstrand described 2 cases of a rare benign, osteoblastic lesion—1 lesion was in a metatarsal and 1 was in the phalanx of a finger [1] Clinically these lesions appeared to Bergstrand to be osteogenic sarcomas, but after he had examined the involved areas of the resected bones he concluded that the lesions were neither inflammatory nor neoplastic and probably were due to embryonal rests. Although these 2 cases of Bergstrand's were osteoid osteomas, the credit must go to Jaffe for establishing osteoid osteoma as a clinical and pathologic entity in his report of 5 cases in 1935 [4] Ten years later in 1945 Jaffe presented a comprehensive review of 62 cases of osteoid osteoma.[5] Since Jaffe's original report, more than 250 cases of osteoid osteoma have been described in the literature and the lesion is well known to the orthopaedist and the radiologist.

Pathologists radiologists and orthopaedists are still debating among themselves as to the exact nature of osteoid osteomas Brailsford,[2] MacKenzie[6] and Hellner[3] believe that osteoid osteomas are only a low grade cortical or subcortical nonsuppurative *inflammatory process in bone* The absence of any clinical signs of infection such as fever or localized redness or increased warmth, together with the absence of any microscopic findings of inflammation in surgical specimens, has led most investigators to the conclusion that osteoid osteoma should be classified as a bone tumor

If osteoid osteoma is a true neoplasm of bone it is a tumor entirely different from any other type of bone tumor No known benign tumor of bone produces so marked a reaction at a distance from the margin of the tumor itself Recently Moberg has reported a case of osteoid osteoma of the fourth metatarsal in which reactive bone formation was not restricted only to the bone in which the nidus was situated but was also present on 2 adjacent bones—the third metatarsal and the proximal phalanx of the fourth toe [7] The periosteal thickening was noted only on the lateral aspect of the third metatarsal that is on the side of this bone adjacent to the metatarsal containing the osteoid osteoma.

The natural course of this disease also argues against its being a true neoplasm The fact that only a very few cases of osteoid osteoma have been found in patients more than 40 years old is the best evidence we have that this disease must heal spontaneously Sherman[8] and Moberg[7] have reported a few cases with clinical and roentgenographic findings typical of osteoid osteoma, in which the disease healed over a period of years and the patients became symptom free The clinical symptoms in these cases apparently disappeared with cessation of the progressive development of the nidus The

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FIG. 1 Preoperative roentgenogram of hips in Case 1 On the right there is seen a small radiolucent area along the inferior aspect of the femoral neck with some sclerosis of bone extending down to the lesser trochanter

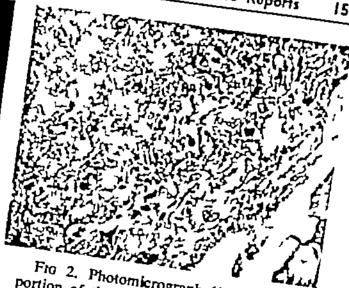


FIG 2. Photomicrograph (× 90) of a portion of the osteoid osteoma removed in Case 1 This shows numerous small trabeculae of osteoid tissue separated by a loose connective-tissue stroma containing osteoblasts, osteoclasts and many small vascular channels.

roentgenographic changes persisted for many years but gradually diminished Of course these cases did not have histologic verification, since biopsy of the lesion would have altered the natural course of the disease

No matter what the exact nature of an osteoid osteoma may be there is little doubt that the condition represents a distinct clinical entity This lesion is seen most frequently in the second and the third decades of life and males predominate over females in a ratio of 2 1 Although the condition is found most frequently in the tibia and the lower two thirds of the femur it has been described as having occurred in every bone of the body except the skull

When the lesion is located near the acetabulum in the innominate bone or in the proximal end of the femur pain in the hip most likely will be the patient s presenting complaint. Because cases of osteoid osteoma are not too common the orthopaedist is apt not to consider this condition in the differential diagnosis of a painful hip If the patient s symptoms and physical findings are at all consistent with a diagnosis of osteoid osteoma a careful roentgenographic search must be made for the presence of this lesion

A total of 17 patients having osteoid osteoma have been seen at this clinic since 1940 Six of the patients complained chiefly of pain in the hip It is with these 6 cases that we are primarily concerned in this presentation In 2 of these cases the lesion was located in the neck of the femur in another 2 cases the lesion was near the lesser trochanter of the femur in the remaining 2 cases the lesion was isolated in the superior ramus of the pubis One case from each of these 3 groups is presented to illustrate the clinical picture of osteoid osteoma of the hip

CASE REPORTS

Case 1 A 33 year-old housewife was first seen at the Cleveland Clinic on September 22 1948 She stated that 2 years previously she had noticed the gradual onset of pain in her right hip with some radiation down the lateral aspect of the thigh. This pain gradually had increased in severity since its onset The pain was now fairly constant and was always worse at night. A single aspirin tablet would give temporary relief from the pain The pain was not aggravated by activity and not relieved by rest. There was no history of any antecedent illness or injury In January 1948 an exploratory operation had been performed to determine whether or not there was any evidence of inflammation in the lateral femoral cutaneous nerve She was told by the surgeon that this



FIG 3 Preoperative roentgenogram of hip in Case 2 The arrow points to an irregular area of decreased density in the superior ramus of the pubis near the acetabulum. This nidus is surrounded by a narrow zone of dense sclerosis.

nerve was not severed because no inflammation was found about it.

Physical examination revealed that the patient walked with a limp on the right leg Internal rotation of the right hip was restricted to 15 other motions of the hip were normal There was some deep tenderness over the anterior aspect of the right hip joint The remainder of the general physical examination was essentially normal.

Laboratory studies, including urinalysis, blood count, hemoglobin determination blood sugar blood Wassermann and Kahn tests, were all within normal limits. Roentgenograms of the pelvis and the right hip which the patient had had taken 2 months previously showed no evidence of any bony abnormality except for slight cortical thickening along the inferior aspect of the femoral neck. New roentgenograms now revealed definite thickening of the cortex along the inferior aspect of the neck of the femur with a small oval, radiolucent area within this zone of sclerotic bone (Fig 1)

On November 2 1948 the right hip joint was exposed through an anterior iliofemoral incision The synovium of the hip joint was thickened and there was an increased amount of fluid within the joint. On the anterior inferior aspect of the femoral neck was an area of roughened cortex. A marker was placed at this site and a roentgenogram was made: it sh that this area coincided with the site c nidus Then a block of bone was rem measuring 15 x 10 x 6 mm., which includ area of soft, reddish tissue correspondi size with the small area of radiolucency on the roentgenogram The walls of the c were curetted and another roentgenogram made to be sure that the entire nidus had removed.

Pathologic examination of the specime vealed the typical histologic pattern of an oid osteoma. There was a well-defined lay dense trabecular bone surrounding a small in which the normal bony architecture completely lost. This area was formed by irregular interlacing trabeculae of osteoi sue separated by relatively abundant, h vascular fibrous tissue containing osteob and numerous multinucleated giant cells o osteoclastic type (Fig 2) A biopsy of joint synovium showed evidence of a nonspe type of inflammation, characterized by s foci of hemorrhage and diffuse infiltratio the synovial membrane by lymphocytes plasma cells.

On the first day postoperatively the pa was certain that she no longer had the pai her hip which she had had prior to the op tion It is now 5½ years since the opera and the patient has remained well with symptoms referable to the right hip

Case 2. An 11 year-old boy was first s at the clinic on May 12 1950 He had b referred by his local physician because c suspected neurologic condition producing p in the child's left groin and hip This pain begun insidiously in June, 1949 about month following an uncomplicated appenc tomy There was no history of any injury pain was described as a "toothache in the h The pain was aggravated by excessive exer and relieved to some extent by rest and asp At first the pain was present only at night, aw ening the child from a sound sleep In the p few months, the pain had been present a during the day The child was observed limp on the left leg when the pain was prese He had been hospitalized elsewhere for months with a tentative diagnosis of tuber losis of the hip but at the time of his c charge the physician told the boy's parents th no disease had been found.

Physical examination was essentially neg tive except for definite tenderness to deep pr sure in the left groin and 1 cm atrophy of t left thigh as compared with the right. The was no restriction of movement in the h

joints. Laboratory studies including urinalysis blood count blood serology and blood sugar were all within normal limits

Roentgenograms of the hip showed a somewhat ill-defined radiolucent area in the superior ramus of the left pubis. There was a shallow zone of sclerotic bone about this area (Fig. 3)

Operation was performed on June 8 1950 The superior ramus of the left pubis was exposed subperiosteally Roentgenographic examination was employed to localize the diseased area accurately Then that portion of the bone was excised piecemeal with osteotome and rongeur and 30 small pieces of bone were sent to the pathology laboratory for examination Another roentgenogram was taken before the incision was closed and this showed that the entire radiolucent area had been removed. The child was relieved of his pain by the second postoperative day It is now almost 4 years since the operation and there has been no recurrence of any discomfort in or about the left hip

Microscopic examination of several of the small fragments of bone showed the characteristic appearance of an osteoid osteoma. There was no microscopic evidence of inflammation

Case 3 A 6-year-old boy was first seen at the clinic on July 24 1952. His mother said that he had been complaining of pain in his left knee and hip for the past year Often this pain would awaken the boy at night. Sometimes, local applications of heat and massage would give relief The child would limp on the left leg when he was tired There was no history of any old or recent injury

General physical examination revealed nothing abnormal. Orthopaedic examination revealed that the child limped slightly on the left leg. There was a full range of motion in the left hip and knee. There was slight atrophy of the left thigh and the left calf as compared with the right. Roentgenograms of the knee revealed nothing abnormal. Roentgenograms of the hip showed an oval area of decreased density approximately 1 cm. in diameter immediately above the lesser trochanter of the femur There was only slight evidence of sclerosis of bone adjacent to this area (Fig. 4)

The operation was performed on August 12, 1952 Through an anterior iliofemoral incision, the neck and the trochanteric region of the femur were exposed subperiosteally A window of bone measuring 1 x 0.5 cm. was removed immediately above the lesser trochanter X-ray examination at the time of operation showed that this window of bone corresponded to the site of the lytic lesion in the bone The bone



FIG 4 Preoperative roentgenogram of hip in Case 3 A rather large oval area of decreased density appears just above the lesser trochanter There is only slight sclerosis of bone adjacent to this area.

in this area was found to be quite sclerotic but beneath the cortex was found an area of soft reddish tissue This area was curetted thoroughly and all the tissue removed was sent to the pathology laboratory for examination. Another roentgenogram showed that the area of decreased density had been removed completely

Microscopic examination confirmed the diagnosis of osteoid osteoma. There was no histologic evidence of inflammation in any of the tissue removed

On the first day after the operation, the child said that he no longer had the former pain in his knee and hip Because it was believed advisable to keep the child from bearing any weight on the left leg for a few weeks a hip spica cast was applied. This cast was removed in 1 month and the child was permitted to be ambulatory without support. It is now 2½ years since the operation, and there has been no recurrence of any discomfort either in the hip or in the knee

DISCUSSION

These cases serve to emphasize the fact that a painful hip may be due to an osteoid osteoma and that this condition must be considered in diagnosis especially if the pa

tient is in the second or third decade of life The relief of pain by small doses of aspirin should make one very suspicious of of the presence of an osteoid osteoma. Pain that awakens a child from a sound sleep at night is also a characteristic symptom of osteoid osteoma

In all of the 6 cases of this series complete and permanent relief from all symptoms was obtained by adequate excision of the nidus or area of decreased density as noted on roentgenographic examination In 2 of the cases a second operation was necessary to obtain complete relief because all of the nidus was not removed at the time of the first operation The use of x ray examination at the time of operation will assist the surgeon to judge the adequacy of the excision and obviate the necessity for further surgery It is never necessary to remove all of the sclerotic bone that is present, but the entire nidus must be excised to produce a permanent cure

If the history and the physical examination are compatible with a diagnosis of osteoid osteoma, it is imperative that a most careful roentgenographic search be made to discover the lesion. The nidus may be small, and there is not always a great amount of bone reaction about it. Roentgenograms should be made with the hip in varying degrees of rotation, and oblique roentgenograms of the pelvis should be made as well as the usual anteroposterior view

While a block dissection of the lesion may give the pathologist a better chance to make an accurate diagnosis, it is neither necessary nor advisable to remove any more bone than absolutely necessary to eradicate the nidus Of course care must be taken to preserve all fragments of tissue removed so that a proper pathologic examination may be made By employing the roentgenogram at the time of the operation, unnecessary removal of bone may be reduced to a minimum This is especially important when the lesion is in the neck or the trochanteric region of the femur since too radical removal of bone in this area might predispose to fracture

Once the clinical diagnosis of osteoid osteoma has been made the only effective treatment is surgical excision of the nidus. Although it certainly is true that osteoid osteomas eventually will heal spontaneously the pain produced by this disease is of sufficient magnitude to warrant surgical intervention The risk of the operation is slight in comparison with the years of continued suffering that the patient will have to endure if the nidus is not removed.

Sherman has pointed out that osteoid osteoma may be associated with changes in the adjacent joint.[9] In Case 1 of this report there was noted at operation marked thickening of the synovium of the hip joint, as well as considerable increase in the amount of normal joint fluid However microscopic examination of the joint synovium revealed only a chronic nonspecific inflammatory process with no evidence of suppuration or active inflammation.

SUMMARY

Osteoid osteoma should be considered as one of the causes of pain in the hip especially in patients between 10 and 30 years old. If the history and the clinical findings are compatible with the diagnosis of osteoid osteoma, a very careful roentgenographic search should be made to discover the nidus if this area is not readily visible on routine x ray examination. The pathogenesis and the exact nature of this disease are not well understood, but the results obtained by adequate surgical excision of the nidus are most gratifying.

REFERENCES

1 Bergstrand, H Ueber eine eigenartige wahrscheinlich bisher nicht beschriebene osteoblastische Krankheit in den langen Knochen der Hand und des Fusses, Acta radiol. 11:596 1930

2. Brailsford J E. Chronic sub-periosteal abcess, Brit. J Radiol. 15 313 1942.

3 Hellner H Reaktive oder neoplasmatische Veränderungen des Skelets? Beitr klin. Chir 181 163 1950

4 Jaffe H L. "Osteoid-osteoma benign osteoblastic tumor composed of osteoid and atypical bone Arch Surg 31:709 1935

5 ——— Osteoid-osteoma of bone, Radiology 45 319 1945

6. MacKenzie W Painful non-suppurative localized sclerosis of long bones, with report of 2 cases, J Bone & Joint Surg 29 49 1947

7 Moberg, Erik Further observations on "corticalisosteoide" or "osteoid osteoma," Acta radiol 38 279 1952

8 Sherman M S Osteoid osteoma review of literature and report of 30 cases, J Bone & Joint Surg 29 918, 1947

9 ——— Osteoid osteoma associated with changes in adjacent joint report of 2 cases, J Bone & Joint Surg 29 483 1947

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Thyroid Function in Legg-Calvé-Perthes Disease—A New Approach to an Old Problem

R W Emerick, M D K E Corrigan, Ph D
A H Joistad, Jr M D, and L E Holly, M D

The possibility of endocrine dysfunction as a factor in the etiology of Legg-Calvé Perthes disease has previously been suggested many times Zemansky discarded the possibility of an endocrine imbalance on the basis that the pathologic changes are not generalized and that other aseptic necroses of bone "never" are found in the same person [7] Ferguson found no association of pituitary-gonadal disturbance or body stature type with this disease but in 75 cases found 1 with associated Köhler's disease and 1 with calcaneal apophysitis [3] Gill believed that some persons with Legg-Calvé-Perthes disease showed definite evidence of endocrine imbalance but he thought that this could not be accepted as the sole or universal etiologic factor [4]

Purcell presented a paper in 1948 which was the stimulus for our studies on the thyroid function of children with Legg Calvé Perthes disease [5] The discussion which followed the presentation of the paper aroused the interest of one of the authors (K E C) who decided to determine the thyroid function of these children using radioactive iodine (I^{131}) Carrier free radioactive isotopes had become available only recently through the Atomic Energy Commission. This program was instituted in the Department of Radiology (L Reynolds M D., Director) at Harper Hospital, Detroit, Mich. Since that time other cases also have been studied in the Radiology Department of Hackley Hospital, Muskegon Mich.

The use of radioactive iodine tracer studies represented a new approach to the study of thyroid function in children as well as in adults The element of co-operation was no longer necessary (but no less appreciated when present) Following the early determination of normal ranges it was found that subtle changes in thyroid function which were not apparent by other diagnostic tests could be discovered by this method

The procedure of doing radioactive iodine tracer studies has been developed by various groups using different technics Considering that radioactive isotopes have been available in sufficient quantities for less than 8 years, it can be appreciated that this diagnostic study is evolving in divergent methods as a result of differences in training, experience and philosophical and scientific approaches to the problems involved Our procedure is described in detail because we feel that it is the best method, and one with which we have been able to demonstrate and check various pathologic findings

To make an accurate diagnostic radioactive-isotope tracer study of the thyroid gland, certain information must be obtained. It is necessary to determine (1) the location of the thyroid tissue (2) the rate of concentration the total concentration and

the retention of the isotope in the thyroid tissue, (3) the variations in concentration of radioactive iodine in the thyroid and (4) the rate the time and the total quantity of urinary excretion of radioactive iodine In order to observe these criteria our patients are hospitalized About 8 A.M on the initial day of the study radioactive iodine is given orally to the fasting subject. Dosage is determined by body weight, 1 microcurie per 3 pounds, the smallest dose being 5 microcuries and the largest 50 microcuries. At various time intervals, usually 2 hours 6 hours, 10 hours, 26 hours and 30 hours following administration of the radioactive iodine, counts are obtained over specific areas. We use a standard Geiger Müller counter with a thin mica window This is shielded by 1.5 cm of lead and is attached to a suitable scaler which has been described previously[2,6] The window of this tube is 2 cm in diameter which with a detachable lead cone can be reduced to 1 cm This will localize small active sources within 0.5 cm., which is satisfactory from a clinical standpoint.

Determination of radioactivity is made over the thyroid area, in the regions of both the lobes and the isthmus The entire thyroid area is scanned with the counter for local areas of hyperactivity or hypoactivity Points over the manubrium, the sternum and the sublingual area also are counted to rule out possible ectopic sites of thyroid tissue Counts are made over the epigastrium to ensure that the radioactive material is passing normally into the small bowel, where it is absorbed. The degree of radioactivity of liver and thigh muscle reflects the amount of radioactive iodine in the circulating blood and the body tissues These data are recorded at each counting period In addition to this an excretion curve is obtained whenever possible Each urine specimen is recorded as to time of voiding and quantity Assay of radioactivity enables one to plot a urinary excretion curve which checks the concentration curve of the thyroid gland. We feel that about 90 per cent of the administered radioactive iodine should be accounted for, the remainder being lost in feces and perspiration

In evaluating the results of radioactive iodine tracer studies, one must keep in mind the possibility of chemical blocks affecting the thyroid gland Iodine in any form except iodized salt will decrease the avidity of the thyroid for iodine This includes Lugol s solution, practically all of the radiopaque solutions used for contrast in roentgenography and many proprietary vitamin preparations which contain iodine Thiocyanate, sulfa drugs and Thiouracil derivatives produce a chemical block of the thyroid gland, and feeding of thyroid substance decreases thyroid function markedly Renal or cardiovascular disease can produce some confusing similarity to a chemical block[1] but in children this occurs infrequently A careful medication history must be obtained in each case but even without history of medication a chemical block becomes apparent in a careful study

Since this study was started in 1948 37 tracer studies have been done on a group of 35 patients with Legg-Calvé Perthes disease Early in our series a few patients were thought to have normal thyroid function but in view of later results it is probable that these were erroneous conclusions and that we missed some small thyroid adenomas. If adequate scanning of the thyroid area is not done and counts are not obtained with the small cone these small areas of hyperfunction are not apparent. In the last 35 patients studied none have shown normal thyroid function Eighteen children have been pure hypothyroid with no evidence of hyperfunctioning adenomata. Seventeen have had thyroid adenomas with elevated iodine concentration. These small toxic adenomas depress activity of the remainder of the thyroid gland so that the net over all thyroid function is decreased to some degree Of the 17 patients with adenomas only 12 had palpable nodules Some of the adenomas were so small that even at surgery the adenoma was not pal



1A 1B

FIG 1 (A) Appearance of the hips, May 1950 prior to radioactive iodine tracer studies. The patient was on usual non weight bearing treatment. No change occurred during the following year (B) Appearance of the hips, October 1951 following administration of thyroid substance for 3 months, in addition to non-weight-bearing Reversal of bone changes and healing with minimal deformity can be observed.

pable in the exposed gland In such instance, if a tracer dose of radioactive iodine has been given prior to surgery the adenoma may be demonstrated by use of a probe counter on the exposed gland. In any event, from our previous tracer study we can tell the operator that the adenoma is located in a specific thyroid area, so that it can be

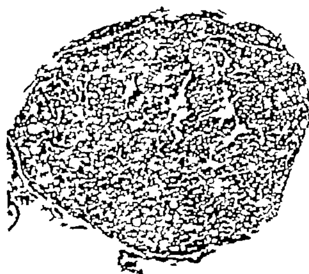


FIG. 2. Photomicrograph of the adenoma removed from patient R. J Note the irregular follicle formation and the thin fibrous capsule This is typical of the adenomas seen in these children.

removed blind. Of 6 patients who had partial thyroidectomies, the adenoma in each instance has been found in the specimen. It is of importance to note that the adenomas which are present do not necessarily have the microscopic characteristics of adult adenomas They do have a thin fibrous capsule and follicle formation There may be lymphocytic infiltration. In general they resemble the so-called metastasizing adenomas found in adults

In addition to the usual non-weight bearing, we have recommended administration of desiccated thyroid to limits of tolerance. In our experience children with Legg-Calvé Perthes disease can tolerate from 1 to 3 gr of thyroid substance daily without showing clinical evidence of toxicity In 1 case of those reported to us from distant institutions, tolerance was not reached until the dosage had been raised to 6 gr per day in a child 9 years old An immediate and entirely satisfactory response was obtained with permanent healing * In cases where hyperfunctioning adenomas are present we have recommended their removal surgically

* We are indebted to F W Feightner M D., of Latrobe, Pa., for information regarding this patient.



4A 4B

FIG 4 (A) Appearance of the hips at the time of radioactive iodine tracer studies. This is 1½ months after the onset of symptoms (B) Following 3 months in a hip spica and administration of thyroid substance 2 gr daily There were no clinical symptoms, and the defect in the right capital femoral epiphysis has disappeared.

In general the course of the disease is dependent upon the stage at which it first is seen and therapy started. In early cases we expect to see improvement or reversal of changes at from 3 to 4 months after therapy is started. Later stages respond more slowly passing through the usual processes of repair and residual changes but in an accelerated fashion. Late stages show little response

In contrast with the foregoing case where treatment was delayed until permanent changes had taken place Fig 4 shows the results obtained when properly controlled thyroid therapy was instituted immediately after the diagnosis of Legg-Calvé Perthes disease was established and the patient was found to be hypothyroidal without complicating factors

In exhibits demonstrating this study we have encountered considerable doubt as to the accuracy of the diagnosis of Legg-Calvé Perthes disease in some of these cases. We have no objection to this as in many of the cases treatment was started early before *the classical changes of fragmentation and* flattening of the capital femoral epiphysis had occurred Reversal of the early changes occurred and the usual progressive roentgenographic changes did not occur How ever a control series would be necessary to answer this valid objection. We did not establish such a series ourselves because of the desire to give each child such benefit as therapy might afford. At the same time, it must be pointed out that a very adequate and satisfactory control series was maintained in that treatment was refused in a significant number of cases similar to those discussed. Refusal was usually on the grounds that the procedure suggested was not in keeping with established orthopaedic practice which of course was entirely true. However the cases have run the classical course without exception, establishing the validity of the original diagnosis In 2 cases, exogenous thyroid therapy was instituted, and a demonstrable early response was produced, after which the therapy was terminated abruptly before significant healing had taken place in each of these cases, immediate and disastrous relapse followed. We do feel that if clinical findings as observed by competent physicians are compatible with the manifestations of *Legg-Calvé Perthes disease* and if roentgenographic changes are present in the capital femoral epiphysis then an early diagnosis of Legg-Calvé Perthes disease is justified and therapy is indicated

SUMMARY

Over the past 5½ years the thyroid function of children with Legg-Calvé-Perthes disease has been studied using radioactive iodine tracers as a measure of thyroid activity Since establishing a proper technic, we have found no patients with Legg-Calvé Perthes disease showing normal thyroid function. Abnormalities observed have been pure hypothyroidism and hyperfunctioning thyroid adenomas with relative hypothyroidism We feel that these patients respond more rapidly to conventional therapy after the adenomas, if present, have been removed surgically and the patient has been placed on thyroid substance in a full tolerance dosage

ACKNOWLEDGMENT We wish to express our gratitude to Eugene Lange, M D., and W L. Brosius, M.D., for all of the pathology studies

REFERENCES

1 Burkhill, F R. Corrigan K. E., and Hayden, H S. The metabolism of radioactive iodine (I^{131}) in patients with cardiac disease Am J Roentgenol 67·42, 1952.

2 Emerick R W Holly, L. E., Jolstad A. H Jr., and Corrigan K E. Diagnostic use of radioisotopes in a general hospital J.A M.A 154 493 1954

3 Ferguson A B and Howorth M B Coxa plana and related conditions at the hip J Bone & Joint Surg 16 781 1934

4 Gill A. B Legg Perthes disease of the hip its early roentgenographic manifestations and its cyclical course J Bone & Joint Surg 22.1013 1940

5 Purcell F H Results of medical management of juvenile epiphyseal disorders, presented before the Clinical Orthopaedic Society of the Central States, October 22, 1948 *See also* Schaefer R. L. and Purcell F H Juvenile osteochondreal (chondro-epiphysitis) hypothyroidism, Am. J Surg. 54 589 1941
Schaefer R L. Strickroot, F L., and Purcell F H The endocrine implication of juvenile chondro-epiphysitis J.A M.A 112 1917 1939

6 Reynolds, L., Corrigan K. E. and Hayden, H S Diagnostic use of radioactive isotopes Am J Roentgenol 68 421 1952.

7 Zemansky A. P., Jr The pathology and pathogenesis of Legg-Calvé Perthes disease (osteochondritis juvenilis deformans coxae) Am. J Surg. 4 169 1928

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Sciatica—Etiology and Treatment

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Any consideration of this subject requires a review of the functional anatomy of the low back.[1,2,3] The two sacro-iliac joints are very stable and strong as a result of their contour and heavy supporting ligaments and are resistant to all except the most severe mechanical trauma. The intervertebral joints are composed of the nucleus pulposa surrounded by the annulus fibrosa bound in place by the anterior and the posterior longitudinal ligaments This forms a relatively resilient structure with a moderate amount of motion and supports the spinal column. This resiliency and motion decrease as the disk ages The 10 interfacet joints have true articular cartilage synovium and capsules with supporting ligaments This anatomic arrangement allows more motion in the interfacet joints than in any of the other joints in the region The intervertebral joints and the interfacet joints combine to support the weight of the upper part of the body and allow a moderate amount of resiliency and motion, but are stable because of their tripod relationship as well as their strong supporting ligaments and muscles. The stability of these joints decreases from above downward because the angle of the sacrum with the lumbar vertebrae tends to decrease the efficiency of the tripod by tipping it forward. Any condition that weakens one portion of the tripod throws an increased strain on the remaining 2 structures This is demonstrated in loss of disk support as a result of rupture or removal It also is demonstrated in the defect in the pars interarticularis, where the facet joints are left without any function of support or stability

The dura, with the nerve roots, lies in the spinal canal immediately posterior to the disk, and the nerve roots leave the spinal column by way of the invertebral foramen, which is bounded anteriorly by the disk, posteriorly by the pars interarticularis and the interfacet joints and to a certain extent by the ligamentum flavum and superiorly and inferiorly by the pedicles The sensory supply to the dura is by way of a meningeal branch of the spinal nerve and the sensory supply to the remaining structures of the back, including muscles and fascia subcutaneous and skin areas is by way of the posterior rami.

ETIOLOGY

Sciatica is caused primarily by 2 mechanisms

1 Root compression syndrome, usually in the region of the intervertebral foramen.

2 Irritation of the nerve endings of the posterior rami or the meningeal nerve In this group could fall any irritation or pathologic conditions in the low back region supplied by these 2 nerves This type of sciatica is true referred pain.

Pathologic conditions in the back and the pelvis which may cause referred sciatic pain are strain of the facet joints, myositis, fibrositis, arthritis herniation of nucleus pul

* Richmond, Va.

posus or early degeneration and irritation in the posterior longitudinal ligament, and in flammatory conditions such as tuberculosis osteomyelitis undulant fever typhoid fever and tumors (both primary and metastatic) Herniation of iliac fat pedicles also has been described as a cause and the early stages of herpes zoster may cause a true referred pain

There are also cases of sciatica due to direct irritation of the sciatic nerve in its distal portions or due to referred pain from tumors or other pathologic processes in the leg, such as trochanteric bursitis or iliopsoas tendinitis Gynecologic and urologic conditions within the pelvis also occasionally may cause referred sciatic pain. Meralgia, paresthetica or obturator neuritis may simulate sciatica.

Sciatica as caused by root compression may result from anything that encroaches upon the nerve usually in the region of the intervertebral foramen This could result from pressure from the disk, arthritis of the bodies of the vertebrae in the form of spurs enlargement or swelling of the inter facet joints pressure from the pars interarticularis as seen in spondylolysis or spondylisthesis and anomalies of these structures or of the nerve roots themselves Sciatica from cord tumors may be the result of referred pain or direct pressure Sciatica may be aggravated or in some cases caused by the edema from repeated diathermy

The differential diagnosis in these conditions depends upon careful history and physical examination, with appropriate roentgenograms and laboratory aids If one keeps in mind the distinction between root compression syndrome and referred sciatica, the diagnosis and the treatment will follow a more logical pattern. This discussion will deal primarily with the diagnosis and the treatment of the mechanical causes of sciatica[4] as has been noted from the previously given etiology these mechanical conditions may cause the sciatica from either referred pain or root compressive syndrome.

The progress of the case also helps to differentiate the referred from root compression The mechanical causes of sciatica may be

1 Trauma
2 A mechanically weak back

The mechanically weak back may produce symptoms spontaneously and is predisposed to repeated episodes of back and leg pain because it is more vulnerable to stress or injury This is manifested in 4 ways one or more of which may be present in the same person

1 Increase in the lumbosacral angle of more than 52 [8,9]
2 Increase in the mobility of the lumbosacral area, resulting from
   A. Obliquely placed or malformed facets[8,9]
   B Spondylolysis or spondylolisthesis[21]
   C. Loss of the support of the intervertebral disk through degeneration or excision
3 Decrease in size of the intervertebral foramen [5 6 7] which makes the nerve root more vulnerable to pressure This is demonstrated in
   A Degeneration or excision of an intervertebral disk without proper surgical fusion with the intervertebral foramen propped open. When there is narrowing of the disk space additional subluxation of the facet joints occurs, which causes further narrowing of the intervertebral foramen This may be demonstrated roentgenographically and associated with it is some posterior displacement of the superior vertebra on the one below [5]
   B In spondylolisthesis and spondylolysis there may be hypertrophy of the cartilagenous plaque, which can cause pressure. Nature's effort at repairing this cartilagenous defect may form osteophytes which also may press directly on the nerve In severe degrees of spondylolisthesis there is actually some pressure from the lamina.[18 19]
   C Congenital anomalies[5,9]
   D Arthritis of the bodies and the facets with spur formation
   E. Edema of the structures surrounding the intervertebral foramen resulting from trauma, such as edema of the

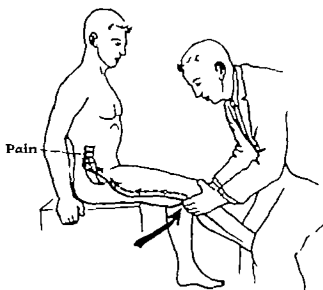


Fig 1 Sciatic tension test (bowstring test) The only motion that takes place is on the bowstringed sciatic nerve

facet joints with simple sprains and edema of a traumatized or a degenerated disk, may occur

4 Decrease in strength in the muscular and the ligamentous supports of the invertebral and the interfacet joints
 A. The posterior longitudinal ligament and the annulus fibrosa may be degenerated as the result of old-age thinning,[10 11 12] and spinal puncture perforating the posterior longitudinal ligament also may cause weakness of these structures [10]
 B Loss of normal muscle support and tone sometimes is seen in pregnancy

All of these conditions allow an increased stress and strain on the structures of the area and are aggravated by repeated injuries In turn, they predispose to disk degeneration and rupture or other pressures on the nerve root. In cases of degeneration or rupture of a disk,[10] and in cases with excess cartilage in the defect in the pars interarticularis or even bone proliferation in the form of ossicles in this defective area, the intervertebral foramen is altered and the nerve is more vulnerable to pressure This may be the result of direct pressure from these structures It may result from the edema of the surrounding structures, such as the capsule of the facet joints or edema of the traumatized disk or the defective area in the pars interarticularis Even in cases due to direct pressure edema plays a part. The nerve itself, as well as surrounding tissue becomes edematous as a result of pressure and irritation. It is the subsiding of this edema in the nerve and the surrounding tissue that allows many cases of sciatica to respond to rest and conservative treatment. For this reason, we believe that even the most severe case of sciatica deserves a trial of conservative treatment.

HISTORY AND PHYSICAL EXAMINATION

A typical history and physical examination in a root compression syndrome is as follows Spontaneously or following varying degrees of trauma the patient has a mild disability because of back pain. The attack lasts several weeks and subsides to be followed by repeated attacks which often are relieved by manipulations from chiropractors or osteopaths These attacks gradually increase in severity and radiate further into the leg and the foot. Disability increases, and the patient no longer is relieved by the above mentioned manipulations He may volunteer that lifting, coughing, sneezing and bowel movements produce leg pain. It is noted that he is pulled forward and to one side during the attacks and during remissions the patient is frequently completely free of pain and disability Usually the patient has had several trials of conservative treatment with bed rest, which initially helped his attacks and sped their recovery In cases that have lasted longer periods of time, the patient may describe a burning or a numb sensation in his leg or foot and at times describes a sensation of formication. Very frequently he describes the pain in the calf as cramplike.

The patient walks with a limp favoring the affected side and often is flexed with muscle spasm and pulled forward with sciatic scoliosis either toward or away from the affected limb Frequently the patient is relieved by a hyperflexed position of the spine which tends to open up the invertebral foramen Pain may be produced in any of the following ways

1. Jugular compression
2. Deep pressure over the fourth and the fifth lumbar interspaces
3. Hyperextension of the back with the patient lying in a prone position
4. Straight leg-raising test
5. Sciatic tension test

The principles involved in this last test have been reported previously,[27] but the procedure described here is new (Fig. 1).

Sciatic Tension Test (Bowstring Test)

The patient is instructed to sit on a table, holding the back as straight as possible and sitting directly in line with no twist. He should brace himself with his hands. The patient is instructed not to move his back or any portion of his body. The affected limb is extended passively at the knee until the patient states that the leg pain is produced. The leg is lowered just below the point of pain and is held clasped between the knees of the examiner with the second and the third fingers of both his hands pressed upon the sciatic nerve in the popliteal space, which has been "bowstringed" by this procedure. Pressure can be made directly over the tense bowstringed sciatic nerve. This causes some local discomfort, but this is far overshadowed by the severe reproduction of the entire sciatic pain and pain up into the back. In borderline cases the position may be altered to one of forward flexion of the head and the trunk. The patient should again be instructed to maintain this attitude throughout the test. This latter position increases the tension of the nerve root and the dura, thereby increasing the sensitivity of the test. This test is accurate because there is no movement of the back, the hip or the knee as is produced by other straight leg-raising tests. The hip, the knee, the ankle and the back are held completely in one position, and the only motion that takes place is a tension on the sciatic nerve produced by the above-described pressure. This test is extremely helpful in differentiating root compression syndromes from referred sciatic pain and also in determining the severity of the root compressive syndrome. The test may be performed on the contralateral leg, and if it reproduces pain on the painful side, this is suggestive that any herniated disk may be in the region of the crotch of the nerve rather than laterally, as it usually is placed. The principle of this test as described by Cram[23] is a production of tension on the tense bowstringed sciatic nerve, which tends to tighten it up at the region of its origin from the intervertebral foramen and to cause motion at this site. If a disk rupture is present, it actually causes it to be pulled over the disk. This test may be performed with the patient sitting in a chair and therefore can be used as a very efficient method of following progress of conservative treatment. A jugular compression test performed with the sciatic nerve on tension in this manner is more sensitive.

Neurologic findings may be weakness of the ankle or knee jerk, weakness of dorsiflexion of the great toe, loss of tone or atrophy in the calf, the thigh or the gluteal area. There may be decreased sensation over the skin areas supplied by the fourth and the fifth lumbar dermatomes or the first sacral dermatome. These skin patterns may be suggestive of the level, but they frequently overlap.

During an acute attack, extreme muscle spasm in the low back limits all low back motion, and frequently the patient is held in a fixed position by this spasm and pain.

All of these findings usually are not found in one case except in rare instances. The severity of pain and the degree of neurologic findings noted, along with the sciatic tension test, serve to differentiate the referred type of pain from the root compressive syndrome. The most frequently positive findings in our surgical cases are presented in the table on the next page.

Roentgenograms are made routinely in all cases with 2 or more views of the back and the pelvis, as indicated. These may show positive evidence of some of the defects mentioned previously, and they always have a supporting negative value when they are normal. Myelograms are not done rou-

	79	12	20
	Disk Pathology	Spondylolisthesis or Spondylolysis	Unstable Back
Local tenderness	74 or 93 6%	11 or 90.3%	17 or 85%
Positive leg raising	71 or 90%	12 or 100%	17 or 85%
Local pressure causing sciatica	52 or 68.5%	10 or 82%	7 or 35%
Reflex changes	33 or 42%	1 or 8 3%	3 or 15%
Sensory changes	31 or 39%	2 or 16 6%	6 or 30%
Atrophy	8 or 10%	1 or 8 3%	4 or 20%

tinely but should be done in those cases which suggest the possibility of cord tumor A negative myelogram is of no help and may be a factor in prolonging a diagnostic survey False positives are very common and have been reported in patients with normal backs in as much as 56 per cent of the cases studied [23] Although we have had no severe reactions there are some very serious ones reported in the literature concerning possibilities of radiculitis following this procedure [24] We feel that if a diagnosis cannot be made on the history and the physical and the x ray findings additional time should be allowed for further conservative treatment or until the diagnosis becomes more apparent. Our experience with myelograms has been as follows.

CONSERVATIVE TREATMENT

Often those patients not improving satisfactorily on conservative treatment are given a Tolserol test[30] 100 cc of 2 per cent Tolserol solution is injected intravenously over a 5-minute period This provides muscle relaxation sufficient to produce visual vertical nystagmus At this point of general muscle relaxation, if the patient's ability to tolerate a straight leg raising test is improved, we feel that he should be given further conservative treatment. However if the patient's ability to tolerate straight leg raising tests is unchanged or made worse we feel that there is probably a root compression syndrome that will require surgical correction

Myelogram Results Confirmed at Surgery

	Disk Pathology	Spondylolisthesis or Spondylolysis	Unstable Back
Tests	16 or 20%	1 or 8.3%	1 or 5%
True positive	10 or 62.5%		
False negative	6 or 37.5%		
True negative		1 or 100%	1 or 100%

Tolserol Test Results Confirmed at Surgery

	Disk Pathology	Spondylolisthesis or Spondylolysis	Unstable Back
Tests	27 or 34%	3 or 25%	1 or 5%
True positive	23 or 85.2%	3 or 100%	
False negative	4 or 14 8%		
True negative			1 or 100%

This is a very helpful procedure in deciding which patient should be given further conservative treatment but in general, once the diagnosis is made our main indication for surgery has been the repeated failure of conservative treatment.

Conservative treatment[12,14-23] consists of rest on a hard bed with the knees and the upper body elevated in Fowler's position Figure 2 shows this position In the hospital it is accomplished easily with a Gatch bed Mephenesin 1 gm every 4 hours combined with local heat, helps relieve spasm but often narcotics are necessary to relieve pain This is continued for from 10 days to 3 months depending upon the progress and is supplemented by flexion exercises (Fig 2) after the acute pain subsides. When the patient becomes ambulatory a flexion cast or a Williams flexion brace is applied and worn until the patient becomes asymptomatic All of these positions and exercises and the use of a flexion cast or brace tend to open up the intervertebral foramen thereby allowing the maximum opportunity for edema and other pressures to subside The patient is advised to do no heavy work until all pain has disappeared and is cautioned against lifting in a strained position at any time Over a 6-year period this conservative treatment was carried out on approximately 1 100 patients with sciatica and was successful enough to prevent the necessity of surgery in all but 155 cases Conservative treatment failed in 14 per cent of our cases The authors performed 155 disk explorations and spinal fusions over this period.

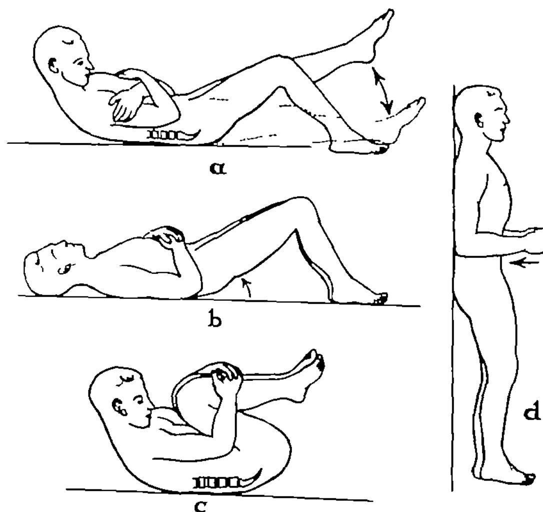


FIG. 2. Exercises flexing the lumbar spine and opening the intervertebral foramen.

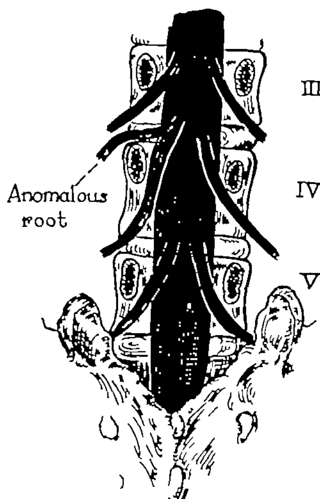


FIG 3 Anomalous branch of L 5 nerve root

OPERATIVE TREATMENT

PATHOLOGY FOUND IN SURGERY

Disk pathology		79
Bulging	16	
Ruptured	53	
Extruded	10	
Unstable back		18
Tight intervertebral foramen		2
Spondylolisthesis or spondylolysis*		12
Total		111

* 3 of these also had extruded disks

One of the cases of tight intervertebral foramen had an anomalous branch of the fifth lumbar nerve root that came off at a right angle to this root at the level of the disk (Fig 3) This anomalous branch went superior to the pedicle and the normal portion of the nerve continued in its normal pathway inferior to the pedicle This made exploration of the disk very difficult, and even after removal of the disk material there was a large amount of tension on this anomalous nerve A portion of the pedicle was removed to relieve this tension This patient is grouped in the fair results

DISK PATHOLOGY

	L-4	L 5	
Ruptured	27	26	53
Extruded	5	5	10
Bulging	10	6	16
Total			79

All of the patients we operated upon had one or more trials of conservative treatment prior to surgery The average age of the patients was 37 The youngest was 17 and the oldest 63 both had ruptured disks. (See table at bottom of page.)

The anesthetic agent was endotracheal or spinal, with a definite preference for the latter We used the convex saddle frame[17] (Fig 4) and we feel that it has many advantages over other methods of obtaining flexion This positioning (Fig. 5) has the following advantages

1 The posterior interlaminal spaces are opened up to the maximum allowing easy access to the disk area often without remov

OCCUPATIONS OF SURGICAL CASES

	DISK PATHOLOGY	SPONDYLOLISTHESIS OR SPONDYLOLYSIS	UNSTABLE BACK
Laborers	40 or 51%	5 or 42%	10 or 50%
Office workers	10 or 13%	1 or 8 3%	1 or 5%
Housewives	16 or 20%	3 or 25%	6 or 30%
Others, e.g., sales and professional	13 or 16%	3 or 25%	3 or 15%



Fig 4 Adjustable padded flexion frame

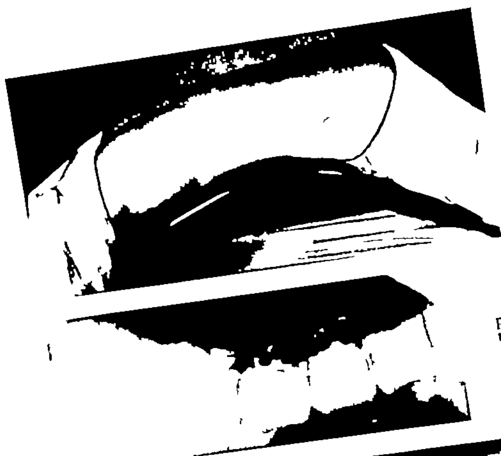


Fig 5 Patient in position on flexion frame. The posterior interlaminal spaces are opened without producing pressure over the abdominal veins.

Fig 6 Roentgenograms of patient in regular prone position no flexion



Fig 7 Roentgenograms of the same patient as in Figure 5 in position over flexion frame Note flattening of the lumbosacral angle and opening of the intervertebral foramen.

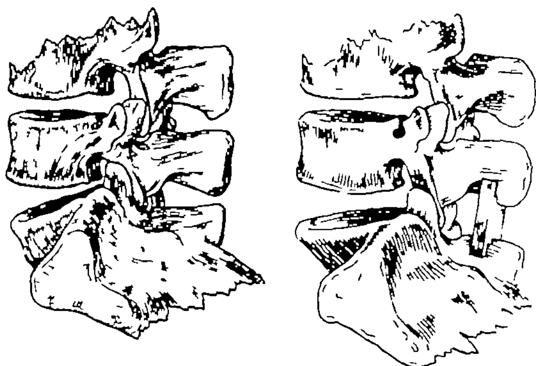


FIG 8 Mortised interspinous-propopening interspaces. (J Bone & Joint Surg 25:58)

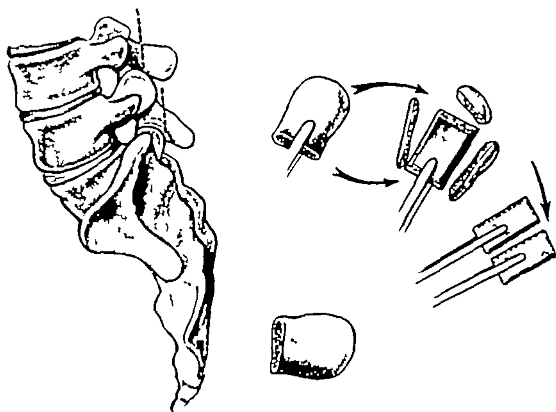
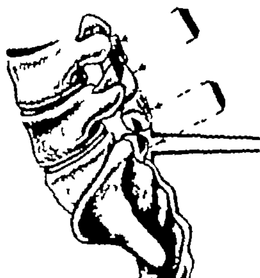


FIG 9 Spinous processes removed and cut as mortise grafts.



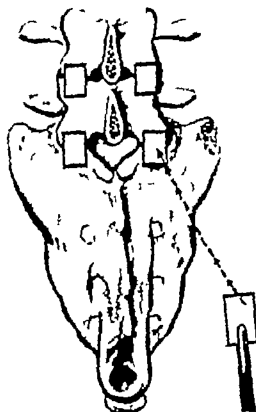


FIG. 10 (*Left*) Mortised grafts placed across facet joints, propping open the inter vertebral foramen

FIG. 11 (*Right*) Beveled grafts mortised into undercut slots in facet joints

ing any bone This can be seen in Figure 6 with the patient lying in a prone position as compared with Figure 7 the same patient flexed on the frame

2 There is no pressure over the abdominal veins, as the engorgement of the dural veins makes possible more accurate surgery with less hemorrhage especially in exposing nerve roots. This lack of back pressure also de creases the possibility of secondary complica tions of the venous system, such as thrombophlebitis or phlebothrombosis.

3 There is a free range of respiratory motion, as the diaphragm can move upward and downward without any back pressure from the abdominal viscera

Shock has not been a problem, but we keep one pint of blood available in the operating room to be used as a preventive in any case where shock appears to be imminent.

The operative procedure followed has been a prop graft employed by one author V R. M[14] (Fig 8) and multiple transfacet mortise prop grafts[16] (Figs. 9 10 11) by the other author (W M D) We also use additional small cancellous chips to supplement this fixation. Both of these techniques incorporate the principle of distracting the facets sufficiently to leave a maximum space in the intervertebral foramen and also to supply additional cancellous minute chips for osteogenesis The precise mechanical stabilization makes early ambulation possible

We routinely explore the fourth and the fifth interspaces on all surgical cases and, if necessary also the third interspace All cases are fused the area to be fused being determined by the amount of pathology found and by whether or not the posterior longitudinal ligament was opened in the exploration. If the posterior longitudinal ligament is opened although no disk is found at the level at which it is opened, we feel that the spine should be fused across this area as well as the area from which a ruptured disk was removed. We make an effort to remove all of the extruded disk material and any additional loose fragments within the disk space are cureted and dissected free A careful inspection is made of the nerve roots, especially in cases of spondylolisthesis or spondylolysis to see whether or not there is any pressure from a cartilagen

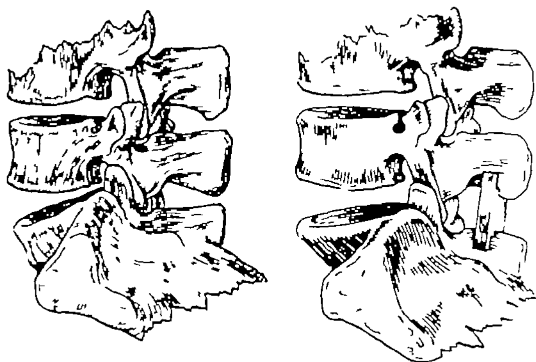


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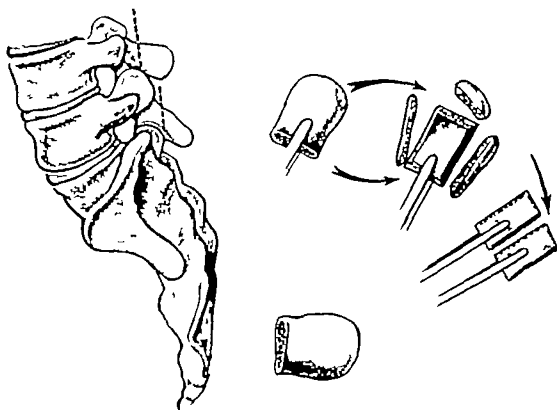
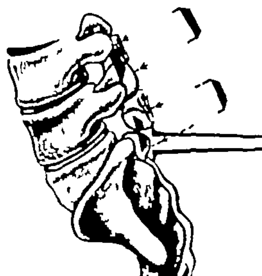


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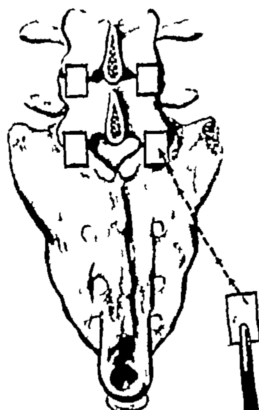


FIG. 10 (*Left*) Mortised grafts placed across facet joints propping open the inter vertebral foramen.

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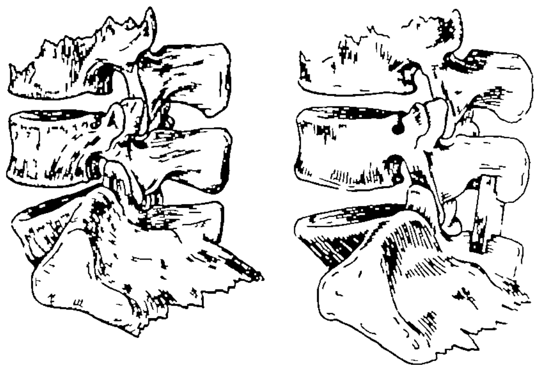


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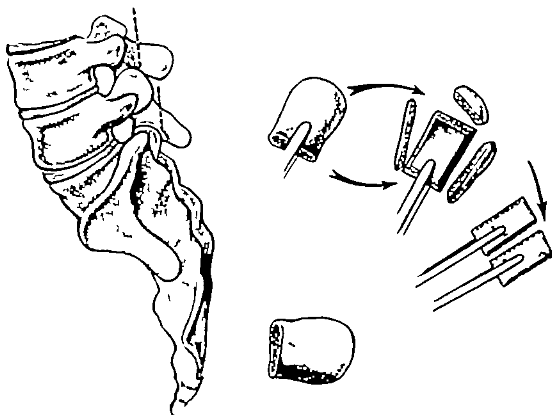
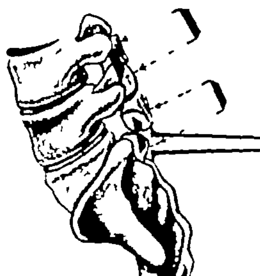


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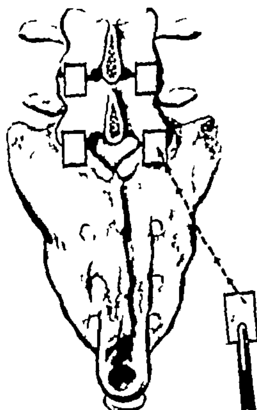


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ous plaque or an osteophyte formation. If pressure is present it is removed carefully Occasionally this necessitates removing the entire lamina, and in our series 4 such cases were encountered. After careful hemostasis *the wound is closed with No 0 chromic* catgut in the fascia and No 0 plain catgut subcutaneously with silk or cotton to the skin.

We feel that the disk should be removed and the spine fused in one operative procedure for the following reasons

1 The unstable spine is the main predisposing factor in degeneration and rupturing of a disk, and removal of the supporting disk renders it even more unable to withstand future trauma

2 The removal of the disk allows for sagging of the vertebrae and a decrease in the size of the intervertebral foramen Therefore we feel that from an anatomic standpoint one should restore insofar as possible the normal relationships of the intervertebral foramen and strengthen the unstable back by performing a prop-type spinal fusion.

3 Psychologically a patient who has a disk removed and the spine fused at one procedure is much more able to make a complete recovery than is a patient who has his disk removed with the understanding that if he has any further difficulties his spine will be fused at that time A patient does not recover as well from 2 operations at separate intervals performed in the same area as he does from a single operation at which time the complete procedure is performed.

4 Economically a very great factor is involved. If the disk is removed at one operation and 18 months later it is found necessary to fuse the spine the patient has 2 periods of total disability 2 periods of partial disability and, in all, loses twice as much time as he would if the procedures were performed at the initial operation In addition, he is much more likely to have a larger amount of permanent disability following the separate procedures than he is following a single procedure. The postoperative care in our cases is essentially the same as that employed by surgeons who remove the disk only

POSTOPERATIVE CARE

The patients are given liberal use of sedatives and narcotics for the first 3 to 4 days and are allowed in any position, provided that they remain recumbent. It is felt that this motion is possible in view of the excellent fixation obtained by the use of the prop grafts precisely fitted.

Initially all patients were recumbent for *21 days following surgery* and then were allowed up in a cast or a brace Recently we have been letting the patients up on the seventh day following surgery wearing a brace or a cast for from 4 to 6 months They may return to light activities from 3 to 8 weeks but are not allowed to do heavy work for 6 months

ACTIVITY FOLLOWING SURGERY

	AVERAGE	EARLIEST
Out of bed	18 days	7 days
Hospital stay	20 days	8 days
Light work	8.5 weeks	1 week
Regular work	17 weeks	6 weeks

COMPLICATIONS

Two cases developed stitch abscesses which responded well to antibiotics and did not in any way affect the results of the operation. Four patients had to be reoperated upon

1 case developed a ruptured disk at a higher level

1 case fell and fractured her spinal fusion 4 years following surgery Bending films revealed motion at L-4 and L 5

1 case ruptured a disk and a pseudarthrosis developed. Bending films failed to reveal any motion. This is the case discussed with poor results

1 case of spondylolisthesis developed a pseudarthrosis. Bending films revealed motion at L-4 and L 5

Three of these patients have returned to their original occupations and the fourth is too recent for adequate follow up One patient died 6 weeks postoperatively at home *from what was thought to be pulmonary* embolus No autopsy was obtained

RESULTS

The results were judged as follows

Poor Those patients who were not im proved or benefited by their operation

Fair Patients still complaining of some pain in back and legs but have returned to previous occupations. They judge their own result to be satisfactory

Good Patients returned to their previous occupations and have only occasional discom fort and pain

Excellent Patients who have no pain and judge their own condition to be excellent

These results were obtained largely by personal interview and supplemented by sending a questionnaire when the personal interview was not possible

Bending Films

This is a careful study of end results. We do not believe that an immovable spine as demonstrated on superimposed bending films necessarily indicates an acceptable re sult. Three of our cases classed as poor results have repeated bending films which do not reveal any motion We feel there is a limitation on the accuracy of bending films in demonstrating motion One out of 3 cases reoperated on for pseudarthrosis had bending films failing to reveal the motion that was demonstrated later at surgery

We have obtained bending films on only a few problem cases and do not do them as a routine procedure *

In 7 cases which were problems we gained the following information from bend

3 cases revealed immovable spines All still are considered poor results.

1 case revealed an immovable spine which subsequent surgery proved to be incorrect.

3 cases revealed motion between the fourth lumbar and the fifth lumbar vertebrae which was found later at surgery

* They were very little help in solving our problems.

Results of 111 Surgical Cases

Excellent	53 or 48%
Good	40 or 36%
Fair	12 or 11%
Poor	6 or 5%
Total	111
Follow-up	
Longest	5 years
Shortest	6 months

Discussion of Poor Results

One case of a bulging disk developed a pseudarthrosis which did not show on repeated bending films but was demonstrated between L-4 and L 5 at surgery It is questionable whether the patient s symptoms are a result of his condition He is a severe hypochondriac and alcoholic and since then has had 4 surgical procedures on other parts of his body such as elevation of the kidneys, gastrectomy vagotomy and similar procedures. He also has been in a mental institution on one occasion.

One case was a 63 year-old diabetic with a ruptured disk She was not fused due to her age Her complaints have been varied, and although we are not sure that they are connected with the surgical procedure performed we do not believe that we greatly improved her condition by treatment She also has been in a mental institution on two occasions following surgery

Results According to Etiology

	Disk Pathology	Spondylolisthesis or Spondylolysis	Unstable Back
Excellent	42 or 53%	5 or 41%	6 or 30%
Good	27 or 34%	5 or 41%	8 or 40%
Fair	7 or 8%	1 or 8 3%	3 or 15%
Poor	2 or 2.5%	1 or 8 3%	3 or 15%
Total cases	79	12	20

One patient with an unstable back in which no ruptured disk was found was able to get about and do her housework in a satisfactory manner Examination clinically and bending roentgenograms show no evidence of failure of fusion however she states that she is unable to do night work As this was her previous occupation, we have listed her case as a poor result.

A second case of an unstable back in which no disk was found had complaints referable to his head extremities and abdomen. There is definite evidence of a pseudarthrosis on bending films but we are not sure whether or not this is responsible for most of his complaints

One patient had pseudarthrosis following a spinal fusion performed elsewhere and was re-fused An excellent fusion is demonstrated on repeated bending films He has vacillated between stating that he had absolutely no pain and professing to be 100 per cent disabled. We feel that we have cured his unstable back but not his unstable personality

The single factor that these 5 cases have in common is this unstable personality

A sixth case of spondylolisthesis has returned to his work which is reasonably heavy but he continues to have pain in his buttocks and down in his thighs and feels that he has a poor result, on direct questioning This patient was done before we were routinely exploring the nerve roots in cases of spondylolisthesis, and we feel that his residual pain is due to the fact that he probably has some pressure on the nerves in the region of the cartilagenous plaque Bending films reveal no motion.

CONCLUSION AND SUMMARY

1 The many causes of sciatica fall into 2 general groups
   a. True referred pain
   b Root compression syndrome
2. A new sciatica tension test (bowstring test) has been described. This is a very sensitive test to differentiate referred sciatica from true root compression syndromes.
3 Conservative treatment should be given a thorough trial in both types of sciatica before any surgical intervention.
4 The surgical treatment should be directed at correcting the mechanical weakness by a spinal fusion propping open the intervertebral space, in addition to removing the local pressure or disk that might be present. Both procedures should be performed at one operation.

REFERENCES

1 Walsh, M N Clinical and neurological aspects of low back and sciatic pain, Radiology 33 681 1939
2. Carey E. J Low back pain a symposium anatomical aspect, Wisconsin M J 39 427 1940
3 Mock, H E. Low back pain, Wisconsin M J 42.389 1943
4 Ryerson, E. W Low back pain a symposium orthopaedic aspect, Wisconsin M J 39·459 1940
5 Haggert G E. Clinical observations on low back pain and sciatic pain S Clin. North America 24 723-730 1944
6 Danforth M S., and Wilson, P D The anatomy of the lumbosacral region in relation to sciatic pain J Bone & Joint Surg. 7 109 1925
7 Putti, V On new conceptions in the pathogenesis of sciatic pain, Lancet 2.53 1927
8 Von Lackum H L. The lumbosacral region. An anatomic study and some clinical observations, J A. M A. 82.1109 1924
9 Ferguson A. B Roentgen Diagnosis of the Extremities and Spine New York Hoeber 1949
10 Barr J S., and Mixter W J Posterior protrusion of the lumbar intervertebral disks, J Bone & Joint Surg. 23 444 1941
11 Saunders, J B de C M and Inman, V T Pathology of the intervertebral disk Arch. Surg 40 389 1940
12. Hauser E. D W Low back pain due to functional decomposition of the back, Wisconsin M J 44 869 1945
13 Henry M O Conservative treatment of the disk syndrome, Minnesota Med. 27 809 1944
14 Breck, L. W., and Basom, W C The flexion treatment of low back pain, J Bone & Joint Surg. 25.58 1943
15 Ralo, F S Intervertebral disk injury resulting from spinal puncture, Surgery 33 690 1953

16. McBride E. D A mortised transfacet bone block for lumbosacral fusion J Bone & Joint Surg 31A 385 1949
17 Shorbe H B and McBride E D A convex saddle frame J Bone & Joint Surg. 32A 452, 1950
18 Gill Gerald Personal communication
19 James, Anthony and Nisbet N W Posterior intervertebral fusion of the lumbar spine, J Bone & Joint Surg 35B 181 1953
20 Schlesinger E. B Use of muscle relaxants as aid in diagnosis and treatment J Bone & Joint Surg 33A 480 1951
21 Gallucio A C. Spondylolisthesis, a general consideration with emphasis on radiological aspects Radiology 42 158 1944
22 Williams, P C The conservative management of lesions of the lumbosacral spine Am Acad Orthop Surgeons Instruct. Course Lectures 10 90 1953
23 Cram R H J Bone & Joint Surg. 35B 192 1953
24 Hurteau E. F., Baird W C. and Sinclair R Arachnoiditis following the use of iodized oil J Bone & Joint Surg 36A 393 1954
25 Trowbridge W V., and French J D The "false positive" lumbar myelogram Neurology 4 339 1954

17

Synovitis of the Hip and Legg-Perthes Disease

A B FERGUSON JR , M D

SYNOVITIS OF THE HIP

Acute synovitis of the hip is one of the most common orthopaedic conditions seen It is an inflammatory condition of the hip of short duration relieved by rest. It looms in the forefront of every differential diagnosis of childhood limp Although this condition is so common it seldom has been described It is related to Legg Perthes disease in that it is potentially preliminary to it

A review of the cases admitted to the Children s Hospital (Pittsburgh) over the last 4 years reveals that the age distribution is very similar to the 3- to 10-year-old group found in coxa plana Occasionally a case as old as 12 may be seen Four out of 5 cases are males

Acute synovitis of the hip is sometimes so mild that its symptoms attract little at tention sometimes it is so severe that it is mistaken for a septic hip joint. Occa sionally cases are recognized only as synovitis by roentgenogram which go on to de velop the typical changes of coxa plana

ETIOLOGY

Very frequently there is a history of respiratory illness from 10 days to 3 weeks prior to the onset of hip symptoms The relationship of these predominantly streptococcal infections to the inflammatory changes of the hip is not clear When trauma looms large in t history the presence of free blood in the joint is postulated. Occa sionally this has been confirmed by aspiration Despite this occasionally clear implica tion *It is apparent that no single etiologic* agent exists whether or not such a joint is an allergic manifestation is uncertain.

CLINICAL FEATURES

The patient is typically a male about the age of 5 Pain usually begins at the knee in the previous 24 hours. The pain tends to become more localized at the hip as the disease progresses Frequently the temperature at the height of the symptoms is as high as 101° occasionally 103° However the leukocytes ordinarily are not increased.



FIG. 1 Toxic synovitis in a 6½ year old male. Note the rounded, increased prominence of capsular shadows of the hip joint on the right side as compared with a straighter shadow on the normal side

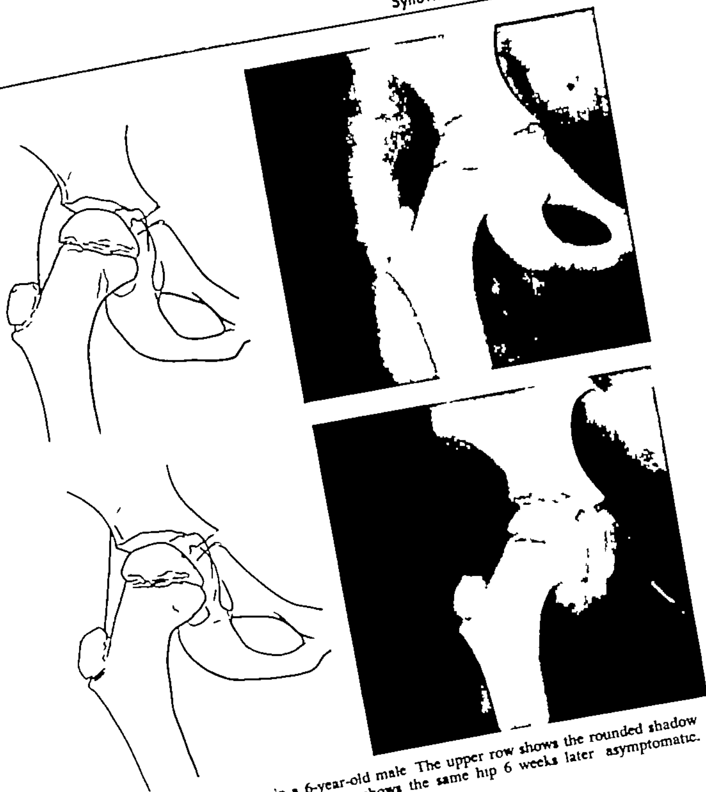


FIG 2. Toxic synovitis in a 6-year-old male The upper row shows the rounded shadow of the hip capsule The lower row shows the same hip 6 weeks later asymptomatic. The capsular swelling is no longer present

The failure of an increase in the leukocytes aids in differentiating the condition from a septic hip when the temperature is high The sedimentation rate may be slightly elevated.

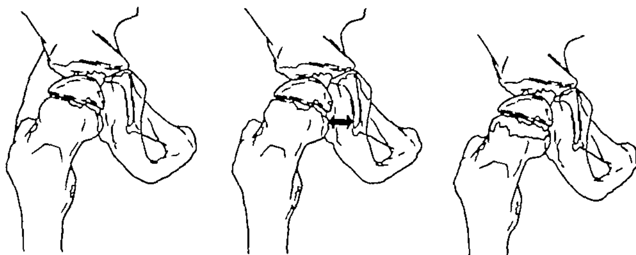
Motion of the hip always is limited There is temporary flexion contracture and limited rotation, particularly internal rotation in flexion, together with limited abduction Palpation of the hip joint reveals both anterior and posterior tenderness.

ROENTGENOGRAPHIC FINDINGS

There are two definite x ray findings The most obvious of these is swelling of the capsular shadows about the hip The rounded, increased prominence of the capsular shadows about the hip is seen best



FIG 3 The roentgen features of early Legg Perthes disease are illustrated. These features are present before the greatly increased density of the femoral epiphysis appears (*Bottom left*) The capsular swelling is diagrammed in the stippled area. (*Bottom center*) The arrow points to the widening of the hip joint. Such widening is noted most reliably in the area indicated by the arrow (*Bottom right*) The stippled area indicates the metaphyseal decalcification that can be found in the roentgenogram.



superiorly and laterally Accompanying this is a minimal widening of the hip joint. Although slight and often found only by measurement, still it is commonly seen. Widening of the hip joint space is recognized more easily in the medial inferior portion of the joint. The anteroposterior view of the hip is most instructive There are no bone changes suggestive of coxa plana

Differential Diagnosis

The hip inflamed because of tuberculous involvement has a chronic history which acute synovitis does not have Septic involvement of the hip must be differentiated by the more definite signs of sepsis—elevation of the white count and shift to the left. Aspiration may be necessary but in practice rarely turns out to be so Other possible underlying causes of inflammation of the hip such as rheumatic fever or rheumatoid arthritis are evident on general physical examination or future course

Treatment

The inflammation about the hip tends readily to subside when weight bearing is eliminated. Traction in line with the flexion contracture is the most certain method of obtaining rapid subsidence of symptoms. While relief from pain is almost immediate it usually takes from 36 to 72 hours to regain full motion at the hip Failure to regain full motion at the hip within 4 or 5 days leads to a suspicion that a more serious etiology underlies the condition

The patient usually is given 1 week of



FIG 4 The development of coxa magna from coxa plana. (*Top*) The roentgenograms reveal the early stage of coxa plana, with increased density of the femoral head added to the early roentgen signs. (*Bottom*) The roentgenograms reveal the same hip 3 years later with widening of the neck and the head, but with a good joint space maintained. Some flattening of the head also has taken place

non-weight-bearing after full motion has been regained to guard against recurrence Recurrences lead to a suspicion of coxa plana.

LEGG-PERTHES DISEASE

Although synovitis of the hip may be preliminary to coxa plana, aseptic necrosis of the proximal femoral epiphysis may start without any previous difficulty at the hip

It is known variously as Legg Perthes disease osteochondritis deformans coxae juvenilis or coxa plana.

The condition may be defined as a disease of the hip limited by age group and largely by sex It results in changes in the femoral head apparently secondary to a loss of adequate vascular supply Its duration is self limited, but its course may result in irreversible mechanical impairment of the hip The age group runs predominantly from 3

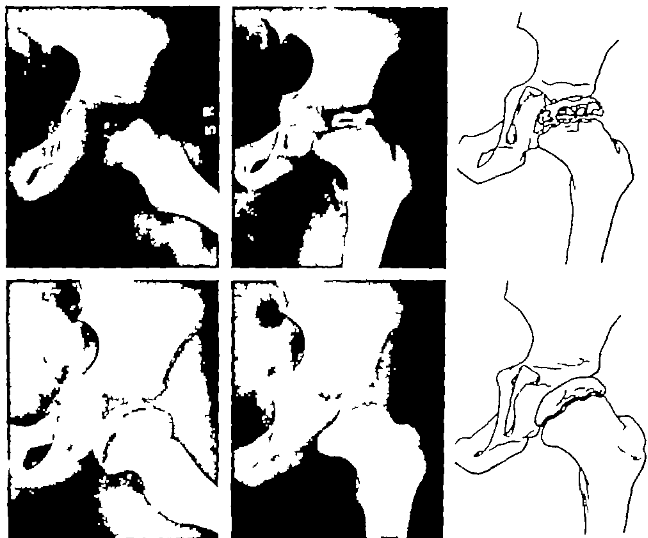


FIG. 5 (*Top*) The roentgenograms reveal changes that are consistent with widening and flattening of the head and are outlined by the dotted line in the diagram. No better result than that outlined can be expected (*Bottom*) The same hip 2 years later with femoral head outlined as predicted from the earlier roentgenogram

to 10 years old, with occasionally a case as old as 12 As in synovitis of the hip the disease occurs predominantly in males (80%) Although Legg-Perthes disease can be bilateral it is most often unilateral (90%)

Etiology

A good understanding of coxa plana can be achieved if it is considered as a disease of the soft tissues rather than of the bone then the swelling of soft-tissue shadows about the hip present on the roentgenogram, is not lost to observation in the presence of rather striking bone changes Ferguson and Howorth have noted the presence of thickened blood vessel walls and thickened capsule in surgically observed cases. They postulated a relationship between previous simple synovitis of the hip or other causes of inflammation at the hip joint and coxa plana. Many have tried to implicate thyroid deficiency because of the occasional occurrence of a similar x ray change at the hip in cretins Conditions resulting in irregular ossification of the femoral head such as chondrodysplasia, bear a superficial resemblance by roentgenogram but are not associated with capsular swelling about the hip or with clinical symptoms and usually have other stigmata of the underlying condition It is possible to have an aseptic necrosis of the proximal femoral

epiphysis in medical embolic disorders This includes infections and physiologic variations such as caisson disease

Aseptic necrosis of the femoral head is seen in patients with congenital dislocation of the hip It has been noted particularly when the hip has been fixed in marked internal rotation The vascular interference runs a much shorter course than in Legg Perthes disease apparently because the underlying cause if positional can be relieved more readily

PATHOLOGY

The joint very seldom has been observed when involved in the active stages of this disease When it has thickening of the capsule and the synovium has been found as well as an increased thickness of the cartilage of the femoral head and neck It is felt that this thickening accounts for the widened joint space—an early roentgenographic feature The synovium may be edematous and hyperemic in stages where motion is markedly limited The area of metaphysis immediately adjacent to the epiphyseal line may be softened by increased vascularity The outward appearance of the femoral head in early stages does not indicate the rather marked changes going on within it. The necrotic bone undergoes a fibrous-tissue replacement process which results in the appearance of radiolucent areas in the dense head shown by roentgenogram Bony areas remaining may be replaced by creeping substitution The fibrous areas are replaced by bone but often only after considerable delay

CLINICAL PICTURE

Characteristically there is a history of limp and pain at the knee usually for a period of 3 weeks to 2 months before being seen. The patient is usually a boy and most often 4 to 6 years old although he may be anywhere in the 3 to 12 year-old group There is a hip flexion contracture readily elicited, and further testing of the motions in flexion develops the limitation of internal rotation and abduction The hip will come to neutral in rotation There may be tenderness both anteriorly and posteriorly to external palpation of the hip joint Measurement of the mid thigh often reveals atrophy of ½ to 1 inch Even if not measurable atrophy is regularly recognizable by palpation of the thigh and the gluteal area The child may be in acute distress In contrast with this picture occasionally and rarely there are children who present such mild features that the disease is recognized only by detailed and thorough examination of the motions of the hip Only by taking the time to make a detailed recording of hip motion particularly in flexion will the examiner avoid the embarrassment of having the case diagnosed more successfully elsewhere.

Stages. Not all cases of Legg-Perthes disease have symptoms immediately at onset. Some cases first are seen when there is already in existence considerable widening of the neck and the joint space with no history of previous symptoms then there are changes which are irreversible These are not apparent when the femoral head is radiolucent but study of the roentgenogram will reveal that the shape of the head can be predicted The stages of coxa plana are discerned best by roentgenogram.

FIRST STAGE (INCIPIENT) There is swelling of the capsular shadows about the hip widening of the joint space and demineralization of the femoral metaphysis in the neck immediately adjacent to the epiphyseal line

SECOND STAGE (ASEPTIC NECROSIS) The changes of the first stage are present in addition, there is definite increase in density of the femoral head in its entirety or in some portion The area supplied by vascular channels from the ligamentum teres may be spared. Often cases are seen first at this stage If no widening of the neck has taken place and the head is outlined fully then no irreversible changes occurred and treatment has the possibility of restoring a good hip

THIRD STAGE (REGENERATIVE) Here

revitalization of the head is taking place as evidenced by the presence of radiolucent areas Widening of the femoral neck also may be evident. One can outline on the basis of the neck width and the joint space remaining, the area of the head not visualized. Often to do so is illuminating. It may be evident that considerable mechanical malformation already has taken place Such malformation still may be compatible with good hip function, but the anatomic outline will not be normal. Still further severity in flattening and widening of the head may be present, so that a poor result is foreordained. However treatment should not allow any further progression if it is to be of value In the last portion of this stage regeneration of the femoral head takes place until the head is filled in completely

Relation to Coxa Magna

Coxa magna is a frequent end result of coxa plana. Its development can be ascribed to the cartilage overgrowth that apparently takes place under conditions of impaired vascularity at the hip Widening of the femoral neck becomes evident in the second stage of coxa plana, when conditions of aseptic necrosis are well established The regenerating head must match this increased width of neck, regardless of whatever other deformity the head may have The head reformed without deformity other than increased size is consistent with good motion at the hip However such increased width results in emergence of the lateral portion of the head from beneath the overhanging acetabular roof Apparently coxa magna can occur without the development of aseptic necrosis of the head that is as an entity quite separate from coxa plana

Treatment

Several authors have noted the importance of bed rest and traction in the treatment of coxa plana It is helpful to remember that the soft tissues about the hip must be restored to normal before the vascular impairment will cease *Until that time the head must be protected from forces which may cause secondary mechanical impairment of the head by flattening and widening.*

Treatment revolves around the maintenance of full joint motion, a normal femoral head outline and a patient who is a well-rounded person, for the disability caused by the late effects of this disease can be a severe deterrent to a person's progress through life

Some deprivation of activity at the stage of involvement may be necessary to give the patient a useful weight bearing joint in the years ahead A strict regimen of non-weight-bearing is essential or there is no sense in advocating this limitation at all.

Removal of the patient from weight-bearing is not enough to prevent deformity of the head. He must gain relief from muscle spasm. This is accomplished best by traction in line with his flexion deformity It should be continued until there is no limitation of motion. It is essential that full motion of the hip be restored regardless of *whatever further form of treatment is used.* Full motion never should be lost from this point onward. It is obvious that placing the patient in a cast does not fall in line with the previous statement.

Should the case be an early one, with minimal soft tissue and bony involvement, it is possible that the time needed to progress to a regenerative stage may be relatively short. These patients regain full motion of the hip quickly and then they may be treated by absolute bed rest with frequent re-examinations to ensure that full motion is being maintained

In the untreated cases the expected time intervals for each stage are as follows first (incipient) from 2 to 4 weeks second (aseptic necrosis) from 1 to 2 years third (regenerative) from 3 to 4 years.

Since absolute co-operation is essential those cases that presumably will be bedridden for at least a year can be allowed up in a non weight-bearing splint. Apparatus which the patient can disengage will be unsuccessful The foot in the splint should

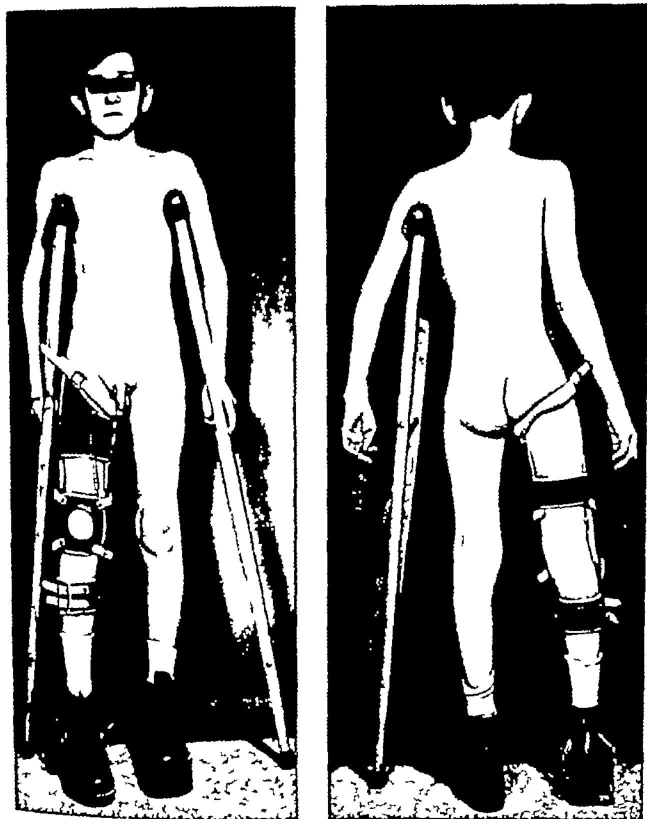


FIG 6 Showing a boy in an ischial weight-bearing splint with patten bottoms useful in the treatment of coxa plana. A 3-inch cork elevation has been placed under the shoe of the sound leg The leg hangs suspended in the brace. Crutches used to start ambulation usually are not necessary thereafter

be suspended 3 inches from the ground. If the patient cannot be counted on, bed rest alone is preferable Full motion at the hip must be maintained, and the patient should be rechecked at 2 month intervals at least

A return to weight-bearing is justified when there have been no new dense areas in the femoral head for 2 months and there are no dense areas in the line of the stress trabeculae of the head. The patient must have full motion at the hip joint There also must be definite evidence that reconstruction is taking place in the head It is not necessary to wait for a completely remineralized head, but sufficient bone structure should be present to arouse confidence in the preservation of that structure

BIBLIOGRAPHY

Eyre Brook A L. Osteochondritis *deformans* coxae juvenilis or Perthes disease results of treatment by traction in recumbency J Bone & Joint Surg. 24 166 1936

Ferguson A. B and Howorth, M B Coxa magna a condition of the hip related to coxa plana, J A M A. 104 808 1935

——— Coxa plana and related conditions at the hip J Bone & Joint Surg. 16 781 1934

Legg, A. T *An obscure affection of the hip-joint*, Boston M & Surg J 162.202, 1910

Mindell, E. R., and Sherman M S Late results in Legg-Perthes disease J Bone & Joint Surg. 33A 1 1951

Pederson H E., and McCarroll, H. R Treatment in Legg-Perthes disease, J Bone & Joint Surg 33A 591 1951

18

Lower Extremity Amputations in Children*

EDWARD T HASLAM M D

This presentation is concerned with major amputations and disarticulations (those proximal to the metatarsals) of the lower extremity in children based on a study of 55 patients followed from 1 to 14 years after amputation † It was initiated in an attempt to determine the optimum age for elective ablations the preferred sites of amputation and the feasibility of prosthetic restoration

Ampulation at any age is an unwelcome procedure since even the best prosthetic restoration fails to duplicate functionally a normal extremity Amputations may be imperative as lifesaving measures. When an extremity is badly disposed as the result of a congenital deformity trauma or disease ablation may be elected.

It is the responsibility of the surgeon

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* Read at the annual meeting of the Association of Bone and Joint Surgeons, March 27 28 1953 at New Orleans, La. (By invitation)

† This group of patients consists of 32 with 34 amputations, made available for study by Garry deN Hough, Jr., M D., Chief Surgeon Shriners Hospital for Crippled Children Springfield Mass., and 23 patients with 25 amputations made available from the Kansas Crippled Childrens Commission Clinic at the University of Kansas Medical Center Kansas City Kans., by James B Weaver M.D., Chief of the Orthopaedic Section. The author is grateful for the permission given him to review and use these cases and for the help and the encouragement supplied by Dr Hough and Dr Weaver

TABLE 1

INDICATIONS FOR OR CAUSES OF AMPUTATION IN 59 EXTREMITIES (55 PATIENTS)

	HIP DISARTICULATION	FEMUR ABOVE LOWER EPIPHYSIS	KNEE DISARTICULATION	TIBIAL DIAPHYSIS	"ANKLE" AND FOOT
Neoplasms					
Malignant	1	5			
Benign		3			
Fractures and Complications		2		9	1
Burns and Complications		3			1
Hematogenous Osteomyelitis		2			
Complications of Reconstructive Surgery				3	
Acquired Deformities Other Than Above		2			
Congenital Deformities			4	13	5
Congenital Amputations				1	4
Total	1	17	4	26	11



FIG 1 (*Left*) Anteroposterior and lateral views of a stump 21 months following amputation at 10 years of age because of severe congenital deformity of the foot. The fibula had been sectioned 1¼ in higher than the tibia and because of either regeneration or overgrowth is seen at this time to be slightly longer The patient began walking with a prosthesis 3 months after amputation and had an excellent, asymptomatic stump (*Right*) Anteroposterior and lateral views of the same stump 15 months later or 3 years after amputation The fibula has increased in length slightly more than the tibia. The stump was painful and was revised at this time, with both the tibia and the fibula shortened. The patient became ambulatory 5 weeks later with his prosthesis and when last seen had reached 18 years of age required no additional operative work and had an excellent stump He walked with practically a normal gait and participated in all activities for his age.

to provide a stump at a level which is the most suitable for prosthetic function and to supervise the patient until maximum function has been obtained [16] This includes careful postoperative management to prevent deformities and to prepare the stump for use with the prosthesis prescribing the proper prosthesis and the necessary training in its use together with appropriate vocational guidance

In planning an elective amputation during childhood, the selection of the optimum age is of the greatest importance In general young children adapt well to physical disabilities which are not painful and it would seem that the advantages of prosthetic restoration at the earliest possible age are obvious Possible disadvantages of early elective amputation might be (1) complications in the stump incident to growth, (2) difficulty in training the child to use the prosthesis, (3) psychological problems of adjust



FIG. 2. (*Left*) Anteroposterior and lateral views of an amputation stump of a 6-year old girl 2 weeks after definitive closed amputation had been done and 6 weeks after she had been run over by a truck, requiring a "guillotine" or open amputation The usual technic was employed Long soft tissue flaps were constructed and the fibula was sectioned well above the tibia. The wound healed uneventfully (*Right*) Anteroposterior and lateral views of the same stump taken 5 weeks later or 7 weeks after the closed amputation. At this time the patient was walking in a plaster pylon without discomfort but had called attention to a "lump" in her stump Although the fibular periosteum had been removed it appears that marked regeneration had taken place. She was fitted with a conventional below knee prosthesis which she used well.

ment to amputation in childhood and (4) special maintenance and replacement problems of the prosthesis in a growing child

Recent literature pertaining to these problems is not extensive and is in some instances contradictory A detailed review is not within the scope of this paper

Fifty five patients with a total of 59 lower extremity amputations, 4 bilateral were reviewed. All amputations had been done prior to 16 years old, with the average age at which primary amputation had been done computed as 9½ The reasons for amputation are given in Table 1 The results of an analysis of each group listed under the specific disadvantages will be presented, with illustrative material where applicable

COMPLICATIONS IN THE STUMP INCIDENTAL TO GROWTH

Among such complications may be over growth of bone with respect to the soft tissues and the skin resulting in the formation of an unsatisfactory spiked " conical stump and eventual ulcer formation at the tip with bony protrusion or a relative shortening of the stump with respect to the opposite extremity due to insufficient bony growth

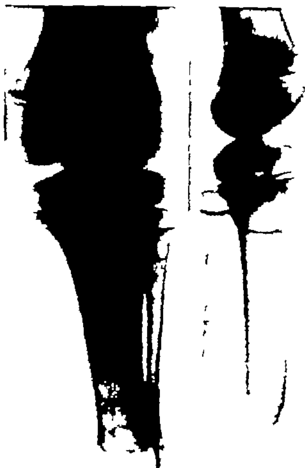


FIG 3 Anteroposterior and lateral views of the amputation stump of the same patient as in Figure 2, taken 16 months after her closed amputation The stump did not require revision at that time but was beginning to give a little trouble and revision undoubtedly will be required. If the previous roentgenograms had not been taken these films might well have been interpreted as indicating overgrowth of the fibula with respect to the tibia following amputation



FIG 4 Anteroposterior and lateral views of an amputation stump which required revision because of "spiking," in the absence of a fibula. These films were taken at 10 years of age, 5 years after amputation because of congenital absence of the fibula and the lateral two digital rays of the foot. The patient had had excellent function in a standard below knee prosthesis until spiking necessitated revision.

because of the absence of the epiphysis through amputation

The first could logically follow below knee amputations since 67 per cent of the growth of the leg occurs from epiphyses at the knee [4] Bone overgrowth as a cause of unsatisfactory amputation stumps in children should be distinguished from ulcer formation on the stump due to circulatory insufficiency excessive or adherent scar tissue or an improperly fitted prosthesis Bony protrusion also may be due to retraction of soft tissues in open amputations not accompanied by sufficient skin traction. In this series bone overgrowth requiring revision was limited entirely to amputations through the tibial diaphysis Such stumps have required revision at periods varying from 2 to 8 years

The cause of such an overgrowth is not known definitely although it has been the subject of much speculation Among possible causes have been stimulation of the proximal tibial and fibular epiphyses following surgery [5,6] with a tendency of the fibula to overgrow the tibia an atrophy of soft parts [13] or retarded growth as compared with the bone.[8] Amputations in the rabbit result in stimulation of the tibial epiphysis.[9] How



FIG. 5 (*Left*) Anteroposterior and lateral views of an amputation stump 14 months after amputation at the age of 5 because of severe congenital deformity of the foot with an extremely short tibia and fibula The stump was excellent and with a prosthesis the patient could take part in practically all activities usual for his age (*Right*) Anteroposterior and lateral views of the same patient 10 months later or 2 years after amputation While this stump is still functioning well, comparison with previous films indicates that the tibia is outgrowing the fibula and is becoming more pointed

ever spiking has been reported in 1 patient with congenital absence or "amputation" through the humeral diaphysis[7] and has occurred in 1 patient with a "congenital amputation" through the tibial diaphysis.[7] In the series here being reviewed it is evident that this is not the only factor Bony overgrowth has been reported as following amputations through the femur,[16] as well as following disarticulation at the knee.[6] This has not occurred in the author's series

In reviewing the records of patients it was not always possible to determine which bone had "spiked" first, but enough information was available to determine that either the tibia or the fibula or both had been affected. One patient appeared to show increased growth rate of the fibula over the tibia (Fig. 1) An interesting explanation of some cases of supposed fibular overgrowth is suggested by 1 patient who had a definitive below knee amputation at the age of 6 following an open amputation for injuries inflicted by a truck Although apparently an extraperiosteal resection of the distal fibula had been done subsequent roentgenograms showed extensive regeneration of the fibula. This might have been attributed to overgrowth (Figs 2 and 3) Spiking can occur in the absence of the fibula as demonstrated by Figure 4 and in some cases the tibia may grow more rapidly (Fig 5)

Spike formations developed in 6 of the 26 amputations through the tibial diaphysis occurring twice in 1 patient No correlations related to sex or race were apparent.

Several methods of preventing spiking have been proposed by various surgeons Epiphyseal arrest has been reported as suc-



FIG. 6 Anteroposterior and lateral views of a below knee stump 8 years after amputation at the age of 10 because of ischemia and infection following a compound fracture of the tibia and the fibula. Previous roentgenograms were unavailable, but clinically the patient had a marked knock knee deformity which suggests that there may have been an early and asymmetrical epiphyseal closure There is a tibiofibular synostosis, and the end of the tibia shows a well-formed cortex. Function with a prosthesis was excellent initially but for the past year he had been having some pain in his knee

cessful.[14,15] This had not been done in any patient in this series Its theoretical disadvantages are the production of possible tender scars on the weight-bearing tibial condyles together with production of a deformity of the stump because of asymmetrical epiphyseal closure and loss of valuable stump length if done at too early an age Excision of the fibula has been advocated,[2] but its routine use is considered inadvisable since spiking can occur even in its absence Tibiofibular synostosis has been recommended.[12] This procedure had not been done on any patient in this series However its spontaneous occurrence in 1 patient did not prevent bony protrusion. In this case both bones spiked

Tibiofibular synostosis occurred in 1



FIG 7 Anteroposterior view of a patient with congenital partial absence of the feet, at the age of 9 months. The patient established gait with a prosthesis at 19 months of age



FIG 8 (*Left*) Anteroposterior and lateral views of the right leg and (*right*) anteroposterior and lateral views of the left leg of the same patient as shown in Figure 7 at 14 years of age. This patient walked very well with modified Symes prostheses and could walk without them. There had been no complications in the stumps during the 14-year period of growth.

other patient In this case, its possible influence in preventing spiking is obscured by the fact that the patient had an early and asymmetrical epiphyseal closure with a knock knee deformity (Fig. 6) It has been suggested that a method of attaching the muscles to the bone end may be designed so that they would exert their mechanical pull and thus be stimulated to grow· this might prevent the complication [9] However no method of accomplishing this has been developed.

There is no reliable method of preventing this complication The soft tissue flaps might be permitted to be a little longer than would be desirable in an adult. The fibula should be cut 1¼ in. shorter than the tibia,[11] and the stump revised as necessary The family should be informed of the probability of necessary revisions This com-

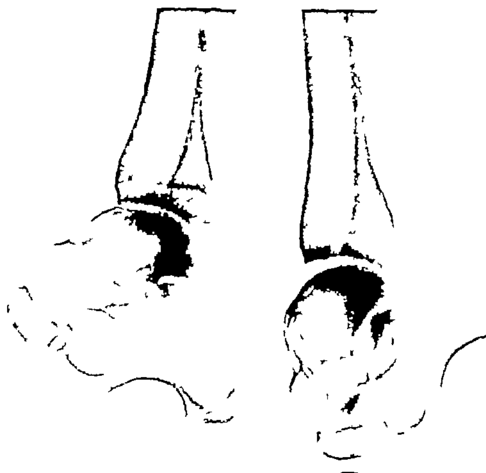


FIG 9 Lateral views of transtarsal amputation, showing the range of active motion which was present 10 years after amputation This patient sustained a traumatic amputation at the level shown at 7 years of age when his foot was caught in a feed grinder According to the parents medical attention was limited to the application of an antiseptic and a bandage by the family doctor The wound healed after several weeks and the patient walked on the stump for 10 years wearing a shoe filler The stump had an adherent cicatrix distally which broke down from time to time and the patient requested and received a below knee amputation when he reached 17 years of age Dorsiflexors, plantarflexors invertors and evertors functioned well, and he walked with a slight calcaneal limp apparently to avoid pressure on the scar There was no varus deformity The patient stated that he preferred his below-knee stump and prosthesis, since with it he could roller skate which previously he had been unable to do. It seems pr[illegible]le that a Symes amputation also would have given good results in this case.



FIG. 10 Anteroposterior and lateral views of an amputation stump resulting from severe burns in early infancy. Although this stump left much to be desired because of scarring from the burns, bone protrusion had not occurred in 8 years of growth, revision had not been necessary and the patient could walk with prosthesis.



FIG 11 Opposite leg of the same patient shown in Figure 10 Information as to the exact amount of growth which has occurred in this stump is not available but it has not "spiked" in 8 years. The curved spur seen extending into the adductor muscles is not considered to be incident to growth

plication does not in any sense completely contraindicate amputations at a below knee level in children but should be considered in each case

Although Symes amputations and transtarsal amputations are looked upon with disfavor by many orthopaedists several patients in this series have had such amputations while actively growing, without spike formations (Figs 7 to 10) Although in some cases the gait may be not quite so good as in a below knee amputation the patient has the advantage of a more simple prosthesis and of the prospects that, in an emergency the stump can be used for weight-bearing without a prosthesis Accordingly it is occasionally advantageous to utilize this level during growing periods re-amputating at a higher level if necessary when growth has been completed It is important to save the distal tibial epiphysis when possible and also to preserve such young tarsal bones as may be present in a patient with a congenitally malformed foot compatible with the fitting of an effective prosthesis

The presence of relative shortening of a stump is more difficult to determine than a bony overgrowth However since the proximal femoral epiphysis contributes only 15 per cent of the total growth in length of the limb [4] short stumps should be expected in amputations at a high level in the femoral diaphysis in an early age group (Fig 11) Therefore it is advantageous to preserve the distal femoral epiphysis whenever possible Disarticulation at the knee joint, although used for many years in adults and recently reported upon favorably [1 10] is not a common site of election However this site has advantages in children by preserving the distal femoral epiphysis [10] Disarticulations have been done in 4 cases in this series and have been very satisfactory (Figs. 12 to 14 Table 2)

TABLE 2

NUMBER OF EXTREMITIES AMPUTATED AT VARIOUS LEVELS TABULATED AS TO LENGTH OF FOLLOW UP AND NECESSITY FOR REVISION DUE TO GROWTH (Does not include revisions of "guillotine" on other stumps prior to function with prosthesis)

	LESS THAN 3 YRS.	3 TO 5 YRS.	6 TO 8 YRS.	OVER 8 YRS.	REVISIONS
Hip Disarticulation		1			
Femur Above Distal Epiphysis	10	4	2	1	
Knee Disarticulation	3		1		
Tibia Above Lower Epiphysis	15	2	5	4	6
"Ankle" and Foot	3	1		7	
Total	31	8	8	12	6



FIGURE 12 *(Caption on page 199)*

The total number of patients followed over sufficiently long periods in which to expect growth complications is not large Therefore conclusions are tentative. However in this series it would seem that the presence either of functioning distal muscle attachments or of a distal epiphysis within a stump will prevent spiking or bony protrusion. While distal epiphyses continue to grow it has not been possible to determine from this study whether their time of closure is precipitated by amputation trauma

CHILD TRAINING

Training the child to use the prosthesis has not been a major problem in single amputations. Bilateral amputations, knee disarticulations and amputations through the femoral diaphysis have been hospitalized routinely for training in the use of the prosthesis. Below knee amputees have not required this intensive training, even at pre school ages. There have been no failures at any age, fortifying the opinion that children should be fitted with a lower extremity appliance as soon as they can stand or walk.[4]

Good function was obtained prior to 2 years of age in a patient with congenital partial absence of both feet. Good function with a standard below knee prosthesis was seen in 2 3-year-olds. One patient with a knee joint disarticulation easily learned a good gait at 4 Two patients with thigh amputations walked with standard above knee prostheses at the age of 6 These are not necessarily considered to be minimal ages but they are the youngest in this series

Satisfactory ambulation with a prosthesis was accomplished in 51 of 55 patients Two with thigh amputations because of a malignancy were not fitted because of early metastases One patient with a thigh amputation because of a flail, short leg following poliomyelitus in infancy fell while learning to use her prosthesis and sustained a fem-



FIG. 12 (Page 198) Anteroposterior and lateral views of the deformed leg of a 7 year-old boy following unsuccessful attempts elsewhere to establish fibulotarsal and fibulofemoral arthrodeses. Knee joint disarticulation was done The cartilage was not removed from the femoral condyles and the patella, which is seen much proximal to its usual position, was not disturbed. The patient became ambulatory 4 months later with an end-bearing prosthesis without a hip joint but with a kick strap and he could walk and run without discomfort.

FIG 13 Anteroposterior view of the same patient shown in Figure 12, 1 year after disarticulation The distal epiphysis is still active The bulbus stump is not a disadvantage if adequate prosthetic service is available as it gives additional control of the prosthesis particularly in lifting it and in controlling rotation

oral neck fracture This was treated by in ternal fixation but was not sufficiently healed at the end of the follow-up period to have resumed prosthetic training One patient with a badly scarred below knee stump fol lowing an infected compound fracture was awaiting reamputation at a higher level 9 months later The stump would not tolerate the prosthesis

In none of these patients was the difficulty of training a reason for failure It would appear from this series that young children are readily taught to use a prosthesis

PSYCHOLOGICAL PROBLEMS OF ADJUSTMENT

Such problems of adjustment are difficult to evaluate No patient younger than 12 at the time of amputation complained of phantom sensations of the extremity Such sensations were recorded or admitted on questioning in about one third of the patients in this series amputated after 12 years of age Such complaints were of trouble some degree in only 1 patient Of course it is difficult to tell what the effect of any physical handicap has been on a patient's personality, but by and large these patients and their parents were happy when seen in the follow-up clinics and had few complaints Several parents who had refused to allow amputations for long periods after it had been advised subsequently volunteered that "if we had known how well our child could walk and how happy we would be with a prosthesis we would have consented to the procedure sooner" Although it has been said that conventional prostheses are not necessary before the age of 9 or 10



FIG 14 (*Left*) Anteroposterior view of a congenitally deformed leg, at the age of 3½ immediately prior to knee joint disarticulation. (*Center and right*) Anteroposterior and lateral views of the same patient's stump 7 years later The femur has continued to grow no revisions have been required and the patient has had excellent function with an end-bearing prosthesis He had had no stump complications and could walk, run and roller skate.

and that during the younger ages more easily lengthened braces are best." It seems wiser as a general rule to fit the child with a conventional type limb as early as possible.[3] Such a limb is much less conspicuous than a brace and subjects the child to less ridicule. In any event, a child requiring an elective lower extremity amputation should have it completed and be fitted and trained in use of the prosthesis prior to beginning school.

Performance with the prosthesis has varied somewhat among patients with comparable levels of amputation but was satisfactory in all cases except as previously noted. Many of these children were active in sports, could dance, roller skate, ski and play sandlot baseball. One child with a below knee prosthesis played football.

SPECIAL MAINTENANCE AND REPLACEMENT PROBLEMS OF A PROSTHESIS FOR A GROWING CHILD

Maintenance and replacement problems vary with the child and with the rate of growth. Limbs may require lengthening or repairs as often as every 6 months and usually replacement every 3 years. Although 2 prostheses for each extremity undoubtedly would be ideal (permitting minor repairs without necessitating crutches)[3] in this series only one was fitted at a time. Obsolescence because of growth in young children was a major economic factor.

SUMMARY

A series of 59 lower extremity amputations done during childhood was reviewed with reference to special problems likely to be encountered during the growing periods.

Spiking, or bony protrusion through the end of the stump, occurred only in amputations at the usual below knee level and did not occur in above-knee amputations with functioning distal muscle attachments or in knee joint disarticulations and Symes amputations which had distal epiphyses. It was not noted in amputations through the tarsals.

No failures in use of the prosthesis because of training problems were encountered. Phantom limb was not complained of when the amputation was done prior to 12 years of age. The patients were a happy group apparently well adjusted. Maintenance of the prosthesis during the growing period with accompanying rough usage of childhood called for constant attention.

CONCLUSIONS

1. Major lower extremity amputations are satisfactory procedures in growing children.

2. Elective lower extremity amputations should be done sufficiently early in life to allow the child to be fitted with a cosmetically acceptable and functionally efficient prosthesis and to be trained in its use as early as practicable, in any event prior to starting school.

3. A young amputee who is trying to walk and is otherwise able can use a prosthesis.

4. Optimum levels for amputations during the period of epiphyseal growth are not always identical with what would be an optimum level in an adult. In boys, knee joint disarticulation is preferable to amputating proximal to the femoral epiphysis, and the Symes amputation or an amputation through the tarsals is preferable to the usual below knee amputation. When contemplating these levels in young girls the surgeon must weigh the advantages of preserving a distal epiphysis against the disadvantages of the prosthesis from the cosmetic standpoint.

5. Disarticulation at the elbow has theoretical advantages over an above-elbow amputation during the growing ages.

REFERENCES

1. Alldredge, R. H. Major amputations, Surg. Gynec. & Obst. 84:759, 1947.
2. Beekman, F. Amputations during childhood. S. Clin. North America 18:425, 1938.
3. Craft, A. W. J. Prosthesis for children, Lancet 246:639, 1944.

4 Frantz, C. H. Prosthetic problems in the juvenile amputee Orthopedic & Prosthetic Appliance J 6 13 1952.
5 Gatewood, M. D and Mullen, B P Epiphyseal growth as cause of conical amputation stump formation, West. J Surg 38.513 1930
6 Kurtz, A D., and Hand, R. C. Bone growth following amputation in childhood, Am J Surg. 45 773 1939
7 Owen, E. A conical stump following intra uterine amputation of the arm, Practitioner 62.37 1899
8 Powers, C A. Further observations on the physiological occurrence of conical stump after amputation in children, M Record 45 423 1894
9 Reich, A. Amputations in childhood and its results with reference to the growth of bone Beitr klin. Chir 68.260 1910
10 Rogers, S P Amputation at the knee joint, J Bone & Joint Surg. 22:973 1940
11 Slocum, D B An Atlas of Amputations, St. Louis, Mosby 1949
12. Streckfuss, H. The Bier method of osteoplastic amputation of leg in young children, resulting in satisfactory amputation stump Zentralbl. Chir 66.2003 1939
13 Todd T W., and Barber C. G The extent of skeletal change after amputation, J Bone & Joint Surg. 16.53 1934
14 Vom Saal, F Epiphysiodesis combined with amputation, J Bone & Joint Surg. 21 442, 1939
15 ——— Amputations in children, Surg., Gynec. & Obst. 76 709 1943
16 Wickstrom, J K. The surgeon's responsibility in the rehabilitation of the amputee Bull. Tulane M Fac. 12.1 1952

19

An Attached Osteoperiosteal Flap for the Repair of Recurrent Direct Inguinal Hernia

ROBERT T MCELVENNY, M D

An excursion into the field of general surgery by an orthopaedist demands some sort of prologue My curiosity was followed by locker room discussions with general surgeons and eventually led to a fixation on the subject. To add further justification for a paper on hernia one must recall that orthopaedists have a tradition in this field of endeavor One outstanding orthopaedic institution was founded in New York City years ago for the purpose of treating the ruptured and the crippled

At times the repeated repair of recurrent direct inguinal hernia becomes a problem because of the lack of good transversalis fascia and other tissue in the region of Hesselbach's triangle The age group to which this condition is common also may suffer from such other afflictions as frequent coughing and spewing aprons of abdominal fat, along with flaccid musculature or prostatic hypertrophy

The problem was undertaken in an attempt to develop a procedure that would furnish an uninterrupted buttress against the protrusion of bowel through the weakened area of this portion of the abdominal wall and at the same time afford a tissue strong enough to provide attachment for the surrounding usable fascia

The principles of the technic were worked out by this author over a period of 6 years they included study with the prepared cadaver and many rehearsals upon fresh specimens in the morgue Following this, William R McMillan applied this technic to actual cases of involved and marked recurrent direct inguinal hernia The results of McMillan's experiences in the first few cases have been published elsewhere [1]

PRINCIPLES OF TECHNIC

1 The usual incision exposes and delineates the operative site and the various structures.

2 The ilio-inguinal ligament is defined and traced to its attachment to the symphysis pubis at the tubercle. Once located the ligament and an attached portion of the tubercle are detached by means of an osteotome

3 Following this the lacunar ligament which attaches the ilio-inguinal ligament to the ramus of the pubis is severed. This allows one to retract the ilio-inguinal ligament and the attached portion of the abdominal wall laterally until the femoral vessels are exposed These vessels are protected and carefully pulled laterally This maneuver exposes about three quarters of the ramus

4 The pectineus muscle can be seen covering the medial half of the ramus. The origin of this muscle on the superior ramus is scraped away gently by blunt dissection a curved peon with its points closed works very well The muscle retracts into the groin No bleeding of any moment is encountered



FIG. 1 Showing the curved osteotome and the periosteal elevator that are great aids in developing a continuous bony flap

The periosteum covering the bone is left intact in all places

5 The complete extent of the superior the anterior and the antero-inferior surfaces of the superior ramus are now in the field *The antero-inferior border of the superior* ramus forms the superior border of the obturator foramen. Attached to this border is a thin fascia that serves to cover the obturator foramen. Directly under this fascia are small but numerous veins that, if disturbed cause some bleeding which packing will control

6 With a sharp osteotome a flap is outlined, with its base left attached to the superior surface of the ramus. The osteotome delineates a flap that takes in an area about ½ inch medial to the junction of the superior ramus with the symphysis continues downward to the upper border of the obturator foramen and crosses this border laterally to the bed for the femoral vessels. Then the osteotome comes upward, skirting medially and parallel with this bed in the bone for the femoral vessels

7 The two vertical lines representing the medial and the lateral extents of the flap are cut decisively by an osteotome to be sure that the outer cortex of the bone is cut through With a curved, sharp osteotome the cortex of the bone forming the upper border of the obturator foramen is cut through gently but definitely All possible closeness to this border must be used, for the length and the subsequent height of the flap depend upon this fact The osteotome should sink deeply here and one should be sure to get through the cortex and into the cancellous *portion of bone* By gently cutting and levering with a curved osteotome one can form a cortical flap with its overlying periosteum firmly attached. This is the most difficult and important step in the procedure

8 *Once this flap is well started*, a sharp periosteal elevator having an arrow shaped head is pushed under the cortical flap and the point enters the cancellous bone By keeping deep in the cancellous bone and by gently elevating and screwing the elevator the flap is raised easily, provided that the vertical cuts have been deep enough to release the cortical continuities (Fig 1 A and B)

9 When the flap is raised and approaches *the junction of the superior and* anterior surfaces of the ramus the direction of the flap changes at almost a 90° angle Here one easily can come out of bone, perforate the periosteum and thus ruin the flap As soon as this area is reached the vertical cuts are extended across the superior surface of the ramus to where the abdominal surface meets the superior surface Now a straight, sharp osteotome is taken, placed under the flap and is driven carefully into the cancellous bone *under the superior surface* of the ramus The object here is to lift the superior cortical surface of the ramus and at the same time to fracture the abdominal cortical surface of the ramus without going through it and cutting the periosteum This is accomplished by very gently and carefully cutting and elevating

10 Now the flap remains attached to the structures on the abdominal surface of the ramus These soft tissue structures along with the fractured (almost green-sticked)

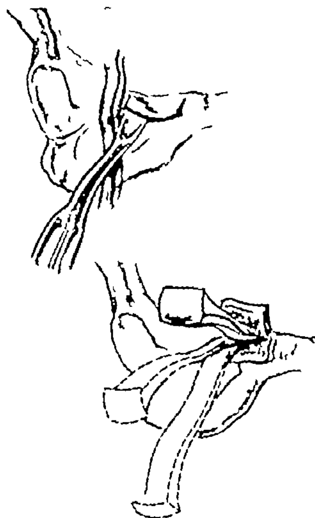


Fig 2. Outline and development of the bone flap

cortical surface of the abdominal face of the ramus act as a hinge This allows the flap to be turned up to cover the area of Hesselbach completely (Figs. 2 and 3)

11 At this point a towel clip may be used to bite holes in the osteoperiosteal flap for the attachment of transversalis fascia brought from above Hesselbach s area and other fascia from the rectus Following this, closure of the structures is routine Care is taken to have these structures over lying the flap reinforcing it and where pos sible attaching to it.

12 The ilio-inguinal ligament is reat tached to its tubercle by means of a very small vitallium nail of the Stuck type This attachment does not have to be anatomic The ilio-inguinal ligament also can be tacked down to the denuded superior border of the pubic ramus This works very well it

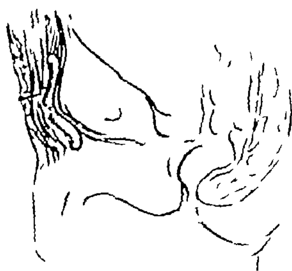


Fig 3 Illustrates raised flap resting upon the peritoneum and covered by the repaired abdominal wall

makes a very tight closure and at the same time affords a backing to the flap This procedure also can be used to close any defect in the region of the femoral vessels

13 If the osteoperiosteal flap is acciden tally cut through in the attempt to raise it along the junctions of the various surfaces, the flap still should be used With a sharp knife the ilio-inguinal ligament and its attached fascia can be split longitudinally to form two joined sheets of tissue The inner sheet can be stitched to the flap and to the fascia of the rectus Then by tacking the outer sheet to the superior surface of the ramus by means of vitallium tacks a good tight closure and repair may be achieved.

CONCLUSION

The purpose of this operation is to afford a wall against which the peritoneum and the bowel may beat The result is that there is no opening through which the bowel may protrude The direction of this buttress is one that tends to direct the peritoneal and the bowel forces down and back into the pelvis

REFERENCES

1 McMillan, W M., and McElvenny R. T A new surgical approach for repair of direct inguinal hernia, J Internat Coll. Surgeons 18 759 1952

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Sciatic and Femoral Nerve Block

DANIEL C MOORE, M.D

The combination of sciatic and femoral nerve block is one of the most useful, yet most neglected, anesthetic procedures applicable in orthopaedic surgery The orthopaedist will find this block most useful for lower extremity problems requiring anesthesia. The technic for a satisfactory sciatic-femoral nerve block is simple to master and it is almost free of complications which makes it useful in either office or hospital practice

Sciatic femoral nerve block has been neglected by most physicians for the following reasons (1) Spinal (subarachnoid) analgesia is regarded as easier to master and less time-consuming to perform and the results are believed to be more predictable (2) Poor results often occur if one blocks only the sciatic nerve for work on the foot. This is because the foot is partly supplied by the femoral nerve (Fig 8) (3) Adequate instruction in administration of these nerve blocks has not been given in the past in many training centers. (4) Some anesthesiologists comment that "this particular block is little employed and that shock and other circulatory phenomena from trauma to the sciatic nerve occur "[1]

At the Mason Clinic during the past 7 years these blocks have been used in more than 1 000 patients and are now the anesthetic of choice in most open and closed orthopaedic procedures of the leg and the foot as well as in closed manipulations of the femur and the knee joint (Table 1)

INDICATIONS

The indications for this method often are dictated by the type of anesthesia as well as by the hospital facilities available in the locale in which a physician practices The advantages of this combination of blocks

TABLE 1 ANALYSIS OF SCIATIC FEMORAL NERVE BLOCK IN 1 000 CASES

OPERATIONS	NO OF CASES	MAXIMUM* ANESTHESIA TIME HOURS	MAXIMUM* OPERATING TIME, HOURS
Closed (Reductions, manipulations, Kirschner wires etc)	229	2	1¼
Open (Reductions, tendon repairs, bone grafts, bone resections)	771	5¼	4½

These are actual times noted on charts. In all instances analgesia lasted longer although the patient had left the operating suite.

seldom is understood by the orthopaedist or the anesthesiologist until the technic is mastered and the procedure given a reasonable clinical trial At the Mason Clinic the following indications have been established

Operations and Manipulations of the Leg and the Foot from 2 Inches Below the Knee Down Any open operation or manipulation of the lower extremity from 2 inches below the knee down irrespective of its magnitude may be performed under these 2 blocks A tourniquet may be applied to the thigh in from 96 to 98 percent of the cases without the patient s complaining of tourniquet pain

Sympathetic Block of Lower Extremity for Vascular Insufficiency Many traumatic injuries, particularly those of the lower extremities result in reflex vasospasm of the part. Block of the sciatic nerve produces a chemical sympathectomy in the lower extremity because most of the sympathetic fibers of the thigh and the leg accompany the sciatic nerve Therefore this block may be used to effect a sympathetic blockade when the physician does not wish to perform a lumbar sympathetic block because he either is unskilled in its technic or is deterred by its complications[3] Also if an operation or a manipulation is necessary the block serves a twofold purpose, i.e it produces anesthesia as well as sympathetic blockade

Manipulation of a Fractured Femur a Locked or a Fractured Knee The sciatic and the femoral nerves innervate most if not all of the muscles of the thigh and the leg, the periosteum of the femur as well as supplying articular branches to the knee Therefore the femur and the knee may be manipulated without pain. However open operations cannot be performed on the knee or the thigh unless the lateral femoral cutaneous nerve which innervates the lateral side of the thigh, and the obturator nerve which innervates the upper inner surface of the thigh and may send an articulating branch to the knee also are blocked.

Relief of Sciatic Pain Sciatic pain which occurs spontaneously or following trauma may be relieved by one block or a series of sciatic nerve blocks with a local anesthetic drug, provided that there is not an intrathecal, an intravertebral or a vertebral source of the trouble

Transportation of a Patient with a Broken Leg In some instances it is necessary to transport a patient with a broken leg from one city or hospital to another Often even if opiates are given bumping over rough roads etc causes marked discomfort. Sciatic and femoral nerve block performed with Pontocaine (tetracaine) will give from 6 to 9 hours of analgesia and often solves such a problem Furthermore if the time consumed in travel is short, the block may last long enough so the surgical procedure or manipulation may be executed without additional anesthesia

Advantages of Sciatic and Femoral Nerve Block Compared with Spinal Anesthesia While it is true that spinal analgesia will create the same operating conditions as sciatic and femoral block and that the spinal technic may be easier to master the following drawbacks to spinal analgesia have made me prefer a combination of sciatic and femoral nerve block wherever it is applicable (1) Following spinal analgesia, the patient is nonambulatory This should be considered when a patient is treated on an outpatient basis or during war or catastrophe when it may be necessary to move patients quickly Following combined sciatic femoral nerve block, patients may be ambulatory on crutches almost immediately (2) Sciatic and femoral nerve block circumvents the 7 to 10 per cent incidence of headache that occurs after spinal analgesia (3) Most patients who complain at the prospect of a contemplated spinal anesthetic will not object to a sciatic-femoral nerve block. (4) Other dangers associated with spinal anesthesia, such as precipitous fall in blood pressure nausea, vomiting, high anesthesia and cauda equina syndrome, are avoided.

Advantages of Sciatic and Femoral Nerve Block as Compared with Inhalation or Intravenous Anesthesia. Combined sciatic and femoral nerve block offers the following advantages that any regional procedure has as opposed to general anesthesia (1) Chemical sectioning of a nerve favors conservation of the physiologic economy of the patient, which is of obvious importance in cardiac disease and diabetes. (2) Emergency procedures may be done immediately without the hazard of vomiting and aspiration, even after a full meal (3) When fluoroscopy is required, this block eliminates respiratory depression or obstruction, which may pass unnoticed in a dark room. (4) Postoperative nausea, vomiting and atelectasis usually do not occur and postoperative depression which may follow a prolonged general anesthetic is avoided. (5) This block reduces the time needed for postanesthetic care and the nursing staff may direct more attention to the care of the extremity (6) In circumstances where it is necessary to limit the amount of time an anesthesiologist must spend with each patient or where no anesthesiologist is available (for example the treatment of lower extremity injuries under catastrophic conditions) this type of block is less time-consuming and more practical than general anesthesia.

TECHNIC

These 2 blocks are not difficult to learn. *It was found by strict adherence to the technic described herein that in a short period of time the percentage of successful blocks performed by the physician learning them for the first time closely paralleled those of the instructor* This is emphasized because many believe that the combination of sciatic and femoral nerve block is difficult, time-consuming and unsatisfactory in a high percentage of cases The author wishes to rectify such impressions and to stress that with patience and some basic understanding of anatomy these blocks can be mastered by most physicians so that successful results are obtained in from 90 to 95 per cent of the cases

It must be remembered that you should strive to start all block anesthetic procedures at least 45 minutes before surgery in order to give adequate time both for instruction and for the block to become established Also you should not hesitate to do a nerve block again if your first attempt is a failure or if only partial anesthesia is obtained.

Premedication. Paresthesias of the sciatic nerve should be elicited to assure a satisfactory block of that nerve. Paresthesias of the sciatic nerve that are characterized by a "shooting, electriclike" pain to some portion of the foot should not be confused with the sensation derived from stimulation of the iliac periosteum, which often radiates into the thigh as a dull, aching pain. The author's dictum for this block is "no paresthesias no anesthesia." Because paresthesias are essential for sciatic nerve block, the patient should be awake and co-operative at the time this block is performed. For this reason, premedication is gauged and selected when the patient is seen on preoperative rounds.

Premedication in the average patient, who is from 20 to 50 years of age is 5 ft. 10 in. (177 8 cm.) tall weighs 150 lb (68 kg) or more and is in good physical condition, consists of from 1/6 gr (10 mg) to 1/4 gr (15 mg) of morphine sulfate with from 1/150 gr (0 4 mg.) to 1/100 gr (0 6 mg) of scopolamine or atropine at the time of *call to surgery A barbiturate is not given* preoperatively After the sciatic block has been executed successfully but prior to the injection of the blocking drug into the femoral nerve from 1½ gr (90 mg.) to 3 gr (180 mg) of Nembutal (pentobarbital) is given intravenously Thus the patient seldom remembers the femoral block or is discomforted by it. If the patient is restless prior to or during the surgical procedure or misinterprets touch as pain, he is given additional sedation usually intravenously such as morphine Demerol (meperidine) hydrochloride pentobarbital or 0.2 per cent

Sodium Pentothal (thiopental) I always bear in mind Labat s admonition that "narcotics must be used to blunt consciousness but not to abolish it "[3]

Drugs Used Any of the common local anesthetic agents may be used. Their dosages etc. are found in Table 2 However, for the past 7 years Pontocaine Hydrochloride (tetracaine) has been the author s choice for the local anesthetic agent Concentrations of from 0 15 to 0 25 per cent and volumes ranging from 30 to 100 cc have been employed. When a bilateral sciatic femoral block is performed the weaker solutions should be employed Adrenalin (epinephrine) 0.2 cc and hyaluronidase 150 turbidity reducing units may be incorporated in the solution. If hyaluronidase is used, epinephrine should be added to the solution or the anesthesia time will be markedly shortened due to wider diffusion and quicker absorption of the drug

The author prefers the crystalline form and mixes his own solutions but ready mixed Pontocaine solutions are adequate [4] In the effective concentrations advocated here it is no more toxic than Novocain Hydrochloride (procaine) and in many cases is less toxic.[5] Not more than 1 mg. of Pontocaine per pound of body weight is administered and as a result its toxic reactions are relatively infrequent in comparison with those of procaine but if they occur they are treated in the same manner

The author prefers Pontocaine as it produces an anesthesia that lasts from 4 to 6 hours, with solutions containing epinephrine giving longest duration (Table 2) There are several advantages based on this lengthy duration [6 to 11] (1) The physician has time to do the block deliberately without rushing there is adequate time to instruct pupils and lengthy dissections may be performed under local anesthesia (2) Sudden changes in operating schedules are permissible since the nerve block does not have to be done again even if the operation is delayed up to 2 or 3 hours (3) The physician has some convenient personal latitude as to timing his blocks which is of obvious importance in private practice where a large surgical schedule prevails (4) The length of anesthesia and postoperative analgesia reduces the amount of postoperative opiates

Materials Needed

One ¾ in (2 cm) 25-gauge Huber point security Lok needle

One 1½ in (3 8 cm.) 22-gauge security Lok needle preferably with short bevel

One 3-in. (7 6 cm) 22-gauge security Lok needle preferably with short bevel

One 4-in (10.2 cm.) 22-gauge security Lok needle preferably with short bevel

TABLE 2 DOSAGE, ONSET AND DURATION OF COMMON LOCAL ANESTHETIC AGENTS

Drug	Dosage		Amount of 1 1 000 Adrenalin	Onset of Analgesia	Duration of Operation
	Unilateral Block	Bilateral Block			
Pontocaine (tetracaine)	40-50 cc of 0.25%	90 cc of 0 15%	0.2 cc*	15 to 45 minutes	6 to 7 hours
Novocain (procaine)	40-50 cc of 1 5%	90 cc of 1 0%	0.2 cc*	5 to 15 minutes	1 to 1½ hours
Xylocaine (lidocaine)	40-50 cc of 1%	90 cc of 0 5%	0.2 cc*	5 to 15 minutes	1¼ to 3 hours
Metycaine (piperocaine)	40-50 cc of 1.5%	90 cc of 1 0%	0.2 cc*	5 to 15 minutes	1 to 1½ hours

* Irrespective of the volume of solution 0.2 cc of Adrenalin (epinephrine) 1 1 000 is not exceeded. With the stronger solution of the drug the onset of analgesia is usually more rapid and the duration of analgesia somewhat longer

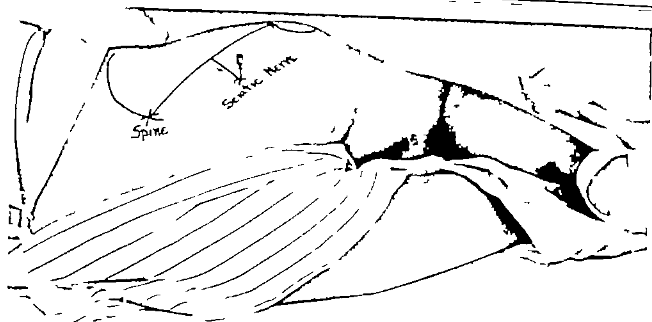
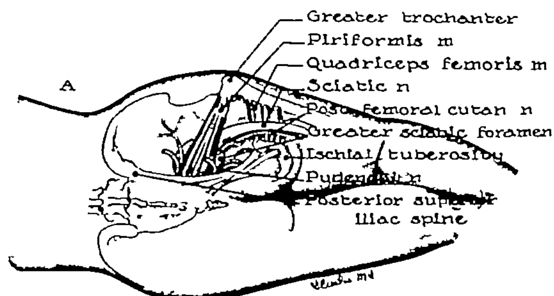


FIG. 1 The patient in position for sciatic nerve block, with a 3-inch needle in place. Note position of the legs, position of X's and the perpendicular position of the needle. Paresthesias were just elicited. The anesthetic was administered for fractured ankle (Moore D C Regional Block, p 206 Springfield, Ill., Thomas)



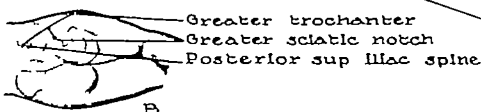


FIG. 2 (A) Deep anatomy of sciatic nerve in relationship to landmarks. (B) Topographic anatomy of landmarks for sciatic block. (Moore, D C. Regional Block, p 209 Springfield, Ill Thomas)

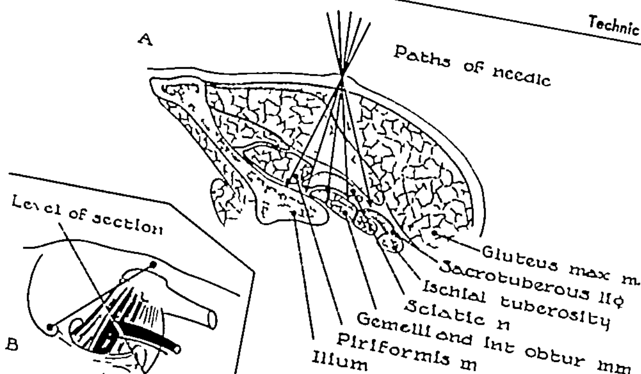


FIG. 3 (A) Direction in which needle should be readjusted when seeking paresthesias of sciatic nerve (B) Level of section. (Moore D C. Regional Block p 212, Springfield, Ill., Thomas)

One 10-cc. Lok syringe preferably with finger rings
One graduated measuring cup preferably stainless steel
One prep cup preferably stainless steel
Four sterile towels
Six sterile sponges
One sterilizer control

Procedure. The methods used for blocking the sciatic and the femoral nerves are essentially those described by Labat, with some personal changes [3,12]

SCIATIC NERVE BLOCK. For sciatic block, the patient is placed in the lateral decubitus position with the side to be blocked uppermost. The under leg is straight, and the hip joint of the upper leg is in 40 flexion 20° to 30 adduction and neutral as to rotation. The knee of the extremity to be blocked is flexed at a 90° angle (Figs 1 and 2) This position places the nerve on the stretch and fixes the anatomic relationships The posterior iliac spine and the superior border of the greater trochanter are located and the skin overlying these 2 points is marked. A straight line is drawn between these 2 points At the midpoint of this line another line perpendicular to it is drawn downward An X mark is made from 1½ in. (3 8 cm) to 2 in. (5 cm) below the base line (Figs 1 and 2) This point should overlie the sciatic nerve as it emerges from the pelvis by way of the greater sciatic notch Then the area is prepared aseptically and draped

In administering the anesthetic, the anesthesiologist stands facing the buttocks of the patient The patient is instructed to say "now" and to avoid movement as soon as he feels a "tingle" or an "electric shock" go down his leg A skin wheal is raised at the predetermined point, and infiltration of the subcutaneous tissues and muscles is performed. A 3-in. (7 6 cm.) or 4-in. (10.2 cm.) 22-gauge security Lok needle depending on the size of the patient, is introduced through the wheal perpendicular to the skin in all planes and advanced until pares-

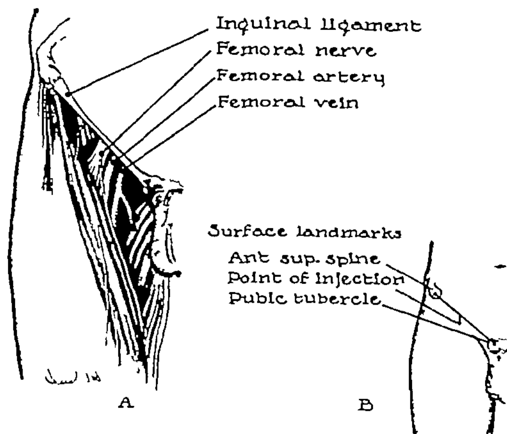
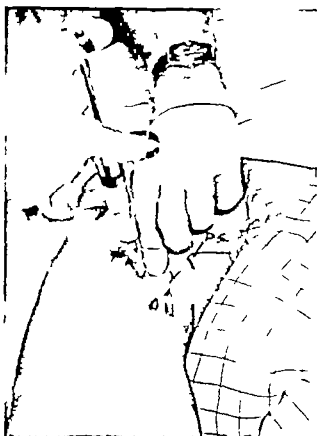


Fig. 4 Landmarks involved in blocking of femoral nerve (A) Deep anatomy (B) Topographic anatomy (Moore D C. Regional Block, p 208 Springfield, Ill. Thomas)



thesias of the sciatic nerve are elicited. Depending on the size of the buttocks the depth to which the needle must be inserted may vary from 2 in. (5 cm) to 4 in (10.2 cm) When bone the rim of the sciatic notch or the spine of the ischium and the bone in its immediate vicinity are encountered but paresthesias are not obtained, the needle depth should be noted The needle does not need to be inserted in any direction more than ¾ in. (2 cm.) past this depth. The nerve usually lies more superficial to these parts of the iliac bone and pares

Fig 5 Index finger displacing femoral artery medially as femoral nerve is injected Paresthesias were not elicited in this patient, but pulsation of the artery against needle was easily felt. A satisfactory block ensued. *F N* femoral nerve *P S* pubic spine *O N* obturator nerve. (Moore D C Regional Block, p 212, Springfield, Ill. Thomas)

thesias often are obtained before the bone is encountered

If paresthesias are not elicited the needle point is withdrawn slightly and reinserted in various directions in a seeking manner, upward and downward in the plane of the body indicated by the short perpendicular line (Fig 3) If this maneuver fails to produce paresthesias it should be repeated after the needle has been directed sacrally so as to enter the sciatic notch When paresthesias are elicited the motion of the needle is stopped and from 15 cc to 25 cc of the local anesthetic solution is injected (Fig 1) If no paresthesias are obtained after numerous attempts from 15 to 30 cc of solution may be injected while the needle point is being moved along the bony rim around the greater sciatic notch in an effort to block the nerve by diffusion of the local anesthetic The diffusion technic of blocking the sciatic nerve is usually unsatisfactory owing to the large size of the nerve and the percentage of partial or complete failure is high

FEMORAL NERVE BLOCK Following completion of the sciatic nerve block the patient is turned to the supine position for femoral nerve block, with his hands placed behind his head The inguinal ligament and the femoral artery are located by palpation A mark is made on the skin ¾ in (2 cm) below the inguinal ligament and immediately lateral to the femoral artery This indicates the position of the underlying femoral nerve (Figs 4 and 5) The area is prepared and draped and a skin wheal is raised at the mark The index finger of the free hand continually palpates and retracts the artery medially while a 1½ in (3 8 cm) 22-gauge security Lok needle without the syringe attached is inserted perpendicular to the skin and advanced until its point lies in close approximation to the lateral side of the artery (Fig 6) If this vessel is pierced, no concern need be felt, the needle being immediately withdrawn from the lumen of the vessel and redirected slightly laterally When the operator removes his hand from the needle the needle should oscillate in rhythm with the adjacent femoral pulse Twenty cc of anesthetic solution now is injected fanwise lateral to the artery, the injection being carried out as the needle is moved in and out (Fig. 7) Care should be taken to see that a wall of anesthetic solution is deposited from the skin to a depth of 1¼ in. (3 2 cm) and laterally from the artery a distance of at least 1 in (2 5 cm) This fanwise injection should be distributed along a cross-sectional plane of the upper thigh No attempt at eliciting paresthesias is made for the femoral nerve because the diffusion technic of blocking the femoral nerve is close to 100 per cent successful However should paresthesias occur 5 cc. of solution should be injected at that point.

DISTRIBUTION OF ANESTHESIA

Surgical analgesia from the combination of these 2 blocks extends throughout the leg and the foot to about 2 in (5 cm) below the patella (Fig 8) Skin analgesia over part of the medial the posterior and a small portion of the lateral surface of the thigh ensues (Fig. 8)

COMPLICATIONS

There were no serious complications from the block technic and only 2 minimal reactions to the local anesthetic agent and/or the vasoconstrictor agent in this series of 1 000 cases In both of these cases 50 cc of the stronger concentrations namely 0 25 per cent Pontocaine Hydrochloride with 0.2 cc of 1 1 000 Adrenalin, was used One reaction occurred in an 18-year-old woman undergoing arthrodesis of the ankle and was characterized by an irregular pulse that reverted to a normal rhythm in 10 minutes without any treatment. The other reaction occurred in a 48-year-old man who had a closed reduction of the ankle It was characterized by blood pressure fall sweating, pallor and faintness Ephedrine sulfate (25 mg) intravenously and oxygen inhalation corrected the condition in 5 minutes

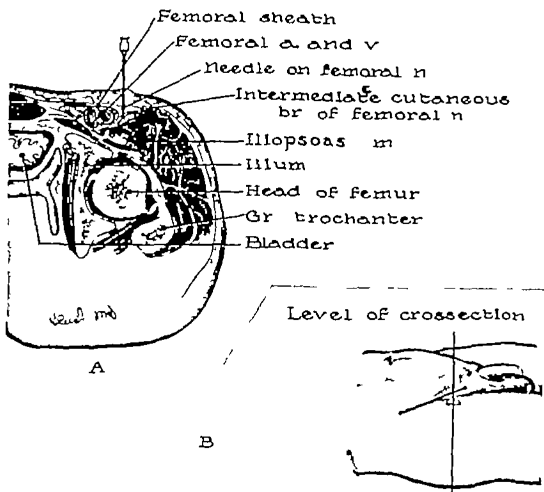


Fig 6 (A) Anatomy of femoral nerve at level of injection, with needle lying next to artery in vicinity of nerve (B) Level of cross section (Moore D C Regional Block, p 213 Springfield, Ill. Thomas)

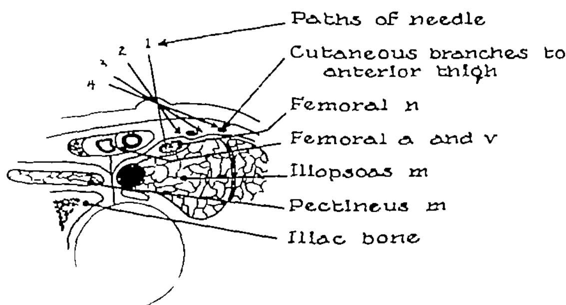


Fig 7 Cross section through the thigh, showing lateral fanwise direction of needle as femoral nerve is injected. Cross section is through same area shown in Figure 6 (Moore, D C Regional Block p 213 Springfield, Ill., Thomas)

SUMMARY AND CONCLUSIONS

An effective technic for combined sciatic and femoral nerve block that has given from 90 to 95 per cent satisfactory blocks in 1 000 cases is described The advantages of this combined block are enumerated and compared with spinal and general anesthesia The reasons why Pontocaine is the drug of choice are discussed The results obtained in this series of cases justify a belief that this block combination is an entirely satis factory form of anesthesia for operations and manipulations of any part of the leg and the foot from 2 in (5 cm) below the patella down as well as manipulations of the knee and the thigh

Perseverance a knowledge of the anatomy involved and strict observance of the principles of the technic described will permit most physicians to master this technic and to obtain satisfactory results

REFERENCES

1 Adriani, J Techniques and Procedures of Anesthesia Springfield Ill., Thomas, 1947
2. Marmer M J The use of sciatic nerve block for producing a vasodilation of the lower extremity and comparative study with paravertebral lumbar sympathetic ganglion block Anesthesiology 13 207 220 1952.
3 Labat G Regional Anesthesia Its Tech nic and Clinical Application ed. 2 Phila delphia, Saunders 1928
4 Bonica J J Personal communications to the author
5 Saklad M quoted from Nowak S Spinal

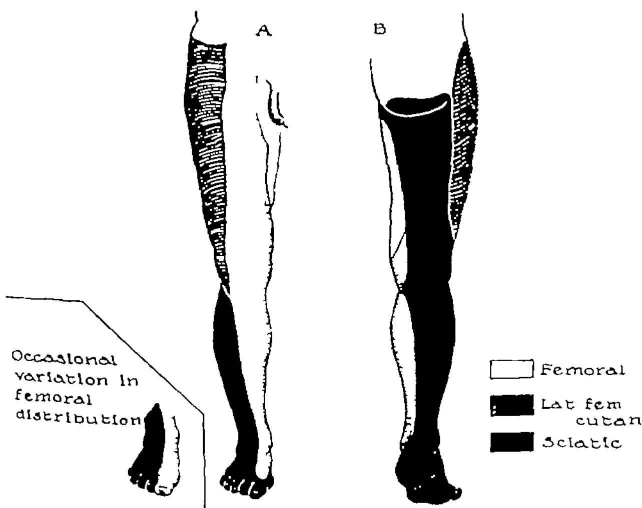


FIG 8 Area of skin anesthesia resulting from block of sciatic nerve and femoral nerve (A) anterior and (B) posterior views (Moore D C Regional Block, p 214 Springfield, Ill., Thomas)

anesthesia agents, methods and indications, New England J Med 213 1226-1235 1935
6 Moore, D C. Pontocaine hydrochloride for brachial block analgesia 150 cases, Anesthesiology 9.281 284 1948
7 ——— The use of pontocaine hydrochloride for nerve block and infiltration analgesia, therapeutic and diagnostic blocks 1 004 cases Anesthesiology 11 65 75 1950
8 Moore, D C., and Bonica, J J Combined brachial block and spinal analgesia for bone graft surgery (report of 83 cases) Anesth. & Analg. 29 43 50 1950
9 Bonica, J J Moore D C. and Orlov M Brachial plexus block anesthesia, Am. J Surg. 78 65 79 1949
10 Moore, D C. Pontocaine solutions for regional analgesia other than spinal and epidural block analysis of 2,500 cases, J.A.M.A. 146 803-808 1951
11 Bonica, J J Regional anesthesia with tetracaine Anesthesiology 11 606-622 1950
12. Moore, D C Regional Block, Springfield, Ill., Thomas 1953

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Scapulectomy and a Method of Preserving the Normal Configuration of the Shoulder

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In general the value of scapulectomy has not been appreciated by the orthopaedic surgeon nor have the indications for this procedure been emphasized sufficiently to promote its use in the cases properly selected Cases of scapulectomy for osteochondroma and fibrosarcoma arising from the scapula have been reported According to Coley Phelps and Carroll have reported cases treated successfully by this procedure In addition, chondrosarcoma limited to the elements comprising the scapula has been eradicated by scapulectomy and a successful cure has been achieved Coley points out that even in cases of frankly malignant tumors of the scapula scapulectomy may be indicated in order to save the arm provided that successful removal of the entire primary tumor is possible In addition to the previously mentioned indications the procedure may be employed successfully in cases of chondromas in which the tumor cannot be removed successfully by partial excision this is also true in destructive lesions such as chronic osteomyelitis and tuberculosis. The author wishes to report 3 cases of scapulectomy performed at the Jefferson Hospital (Philadelphia) one of these was performed for chondrosarcoma, another for a desmoid tumor involving the muscles of the scapula and the third for chondromyxoid fibroma of the scapula. Also a modification of the orthodox scapulectomy is presented this technic preserves the normal configuration of the shoulder and precludes dropping of the shoulder

TECHNIC

The patient is placed on the unaffected side close to the edge of the table the arm is draped separately Two skin incisions are made the first begins immediately lateral to the tip of the acromion and extends along the spine to the vertebral border of the scapula The second incision is a continuation of the first it extends downward along the vertebral border to the inferior angle of the scapula The resulting flaps are reflected exposing the dorsal surface of the scapula with the muscles attached (Fig 1 A) The horizontal limb of the incision is deepened to divide the insertion of the trapezius muscle and the deltoid muscle These are detached from the acromion process and the spine of the scapula and retracted Then the anterior portion of the incision is extended around the upper end of the humerus The deltoid is detached from the outer third of the clavicle to bring into view the coracoid process with its muscular attachment the coracoclavicular ligaments and the insertion of the rotator muscles The acromioclavicular ligaments are severed the scapula is mobilized still further by dividing the muscular attachments to its vertebral border namely the levator scapulae the rhomboids the serratus magnus and the teres major muscles.

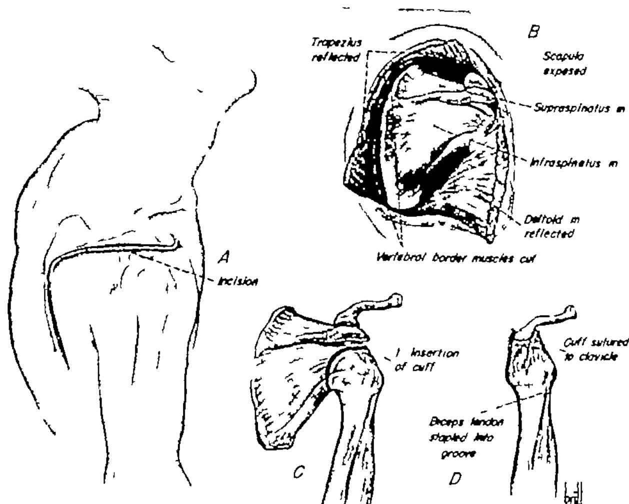


FIG 1 (A) Skin incisions. (B C D) Approximately 1 inch of the tendinous insertion of the rotator cuff is left attached to the upper end of the humerus The head of the humerus is placed under the distal end of the clavicle and the tendinous tissue is anchored to the end of the clavicle by interrupted sutures passing through drill holes in the clavicle.

This is followed by a division of the muscular attachments to the coracoid process these are the pectoralis minor the coracobrachialis and the short head of the biceps brachii Then the coracoclavicular ligaments are identified and they are divided close to the clavicle

The musculotendinous cuff is divided approximately 1 inch from its insertion leaving a broad band of thick tendinous tissue attached to the humerus This incision also divides the coracohumeral ligament and the tendon of the long head of the biceps the distal end of which should be grasped with an Allis forceps in order to prevent its retraction distally and beyond reach Resection of the apula is completed by cutting the remaining portion of the fibrous joint capsule and the muscular attachments After all bleeding has been controlled the long head biceps tendon is anchored to the humerus This is achieved readily by scarify ing the floor of the bicipital sulcus with a curet or a gouge and anchoring the tendon in the newly made trough by several interrupted sutures passing through the tendon and the lateral walls of the sulcus as an alternative the tendon may be stapled to the humerus Then the arm is stabilized against the thorax by attaching the remaining portion of the musculotendinous cuff to the end of the clavicle This is executed by passing several drill holes through the clavicle and anchoring the cuff to it by



FIG. 2 (A *Top left*) Chondrosarcoma of the scapula (Case I J A) Note the nodular tumor implicating the acromion and the spine of the scapula (B *Top right*) Note the characteristic roentgenographic features of a chondrosarcoma, destroying completely the acromion and the spine of the scapula and involving the neck of the scapula. (C Bottom left) Photomicrograph (× 200) of tissue obtained from the resected scapula. Note the pleomorphic features of the chondroblasts and the paucity of stroma. (D *Bottom right*) Roentgenogram taken 3 years after scapulectomy All the tumor has been excised no recurrence is demonstrable Note the extreme downward displacement of the head of the humerus

means of interrupted sutures Finally, the trapezius and the deltoid muscles are approximated, and the skin incisions are closed with interrupted sutures. A drain is placed in the dependent part of the wound it is removed after from 24 to 48 hours Dry dressings are applied making firm pressure on the wound The arm is immobilized by a Velpeau bandage The arm is maintained fixed to the side for a period of approximately 3 weeks However during this period the hand, the wrist and the elbow are exercised freely After a period of 3 weeks the Velpeau bandage is removed, and active motion is encouraged in all the joints of the extremity

ADVANTAGES OF THIS PROCEDURE

In the orthodox type of scapulectomy the patient invariably exhibits a dangling arm and is unable to fix the arm against the thoracic cage In addition as time elapses the weight of the arm drags the humeral head far below the level of the clavicle and by so doing forms a hideous deformity in the region of the shoulder This is well depicted in the case of J A (Fig 2 D) On the other hand, the procedure described above anchors the humeral head in close proximity to and beneath the clavicle providing a round contour for the anterolateral aspect of the shoulder also it provides a point of fixation for the humeral head when the patient attempts to stabilize the arm It is interesting to note how well the patient can fix the arm under the clavicle and against the thorax by contracting the deltoid muscle Although no abduction is possible these patients stabilize the upper arm firmly against their chest wall and under the clavicle and can use the elbow the wrist and the hand freely

CASE HISTORIES

Case 1 J A aged 41 According to the patient s statement he sustained an injury to his left shoulder approximately 10 years prior to his first visit to the orthopaedic clinic of the Jefferson Hospital He was first seen on April 26 1951 A few months after the injury the patient noticed a small tender swelling on the top of the shoulder He sought no treatment for approximately 1 year Finally roentgenograms were taken, and a needle biopsy of the tumor mass was done A diagnosis of chondrosarcoma was made and he was given irradiation therapy Following this he was told that surgical intervention was not indicated and that nothing else could be done At his first visit to our orthopaedic clinic this patient had constant pain in the shoulder girdle and volunteered the information that the tumor mass was increasing rapidly in size Examination at this time disclosed a nodular mass implicating the upper end of the shoulder all motions at the shoulder joint were painful However he was able to abduct the arm approximately 135 and had a small range of internal and external rotation without pain (Fig 2 A) Palpation of the area disclosed a large nodular mass involving the spine of the scapula and the acromion process. The skin was freely movable and there was no evidence of any lymphatic involvement in the axilla or in the neck. A survey of his roentgenograms disclosed findings consistent with chondrosarcoma implicating the scapula and the entire acromion (Fig 2 B) A biopsy disclosed the lesion to be a chondrosarcoma. On April 27 1951 he was admitted for a scapulectomy which was performed promptly however the cuff of the humerus was not anchored to the clavicle as described above This patient when last observed in May 1954 showed no evidence of recurrence However as will be noted in the roentgenogram, the humerus has descended to considerable distance from the clavicle and the patient has no stability of the upper arm when an attempt is made to employ the extremity for any useful activity (Fig. 2 D) He is capable of anchoring the humerus to the side of the thorax by means of the pectoralis major muscle and by so doing he is able to provide a little stability during the course of his work His chief complaint is a constant "dragging and pulling" sensation in the neck on the affected side

Case 2. (Fig. 3) W M., aged 38 This patient was seen first on July 8 1952, at which time she was complaining of generalized pain in the region of the left shoulder girdle The onset of this pain had been gradual beginning approximately 1 month prior to the time that she was seen in the clinic A local surgeon examined the patient immediately after she noticed the symptoms and observed a mass on the posterior region of the scapula. The mass was tender and painful however it did not implicate the overlying tissues The skin was freely movable, and on June 23 roentgenographic survey of the shoulder disclosed that the lesion implicated the





FIG. 3 (A *Top left*) Chondromyxoid fibroma of bone (Case 2 W M) Roentgenographic features in this instance are not characteristic of the lesion however some radiolucency of the body of the scapula is discernible (B *Top right*) Gross specimen of the scapula, together with its enveloping musculature (C *Bottom left*) Photomicrograph (× 100) of tissue obtained from the gross specimen Note the spindle-shaped cells dispersed loosely in a myxoid intercellular matrix Some areas have assumed chondroid features. (D *Bottom right*) Roentgenogram taken 1 year after scapulectomy Note that the head of the humerus is still immediately under the clavicle and that the general configuration of the shoulder is preserved



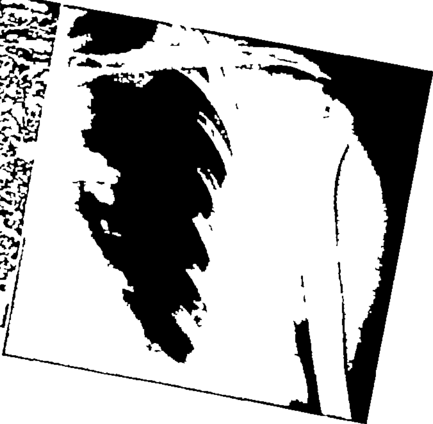




FIG 4 (A. *Top*) Desmoid tumor (Case 3 R. B) Note that only the head, the neck and the spine of the scapula remain no implication of the bone is demonstrable (B *Bottom*) Gross specimen of tumor tissue found along the inferior neck of the scapula. In this photograph it appears as dense greyish white fibrous tissue



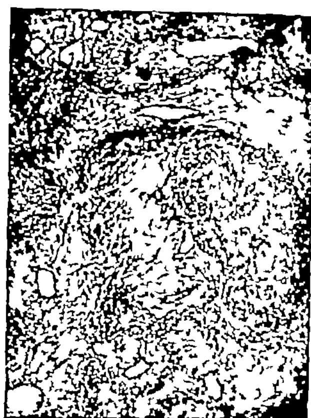


FIG 4 C Photomicrograph (× 100) Note the connective tissue proliferation between the muscle fibers which are being replaced by tumor tissue

entire body of the scapula the surrounding soft tissues appeared to be free of any involvement. A biopsy of the mass was done and a diagnosis of chondrosarcoma was made A review of the histologic sections by another pathologist disclosed that an erroneous diagnosis had been made the cytologic features noted were consistent with chondromyxoid fibroma of bone. This case is of special interest because, based on the first biopsy report, a thoracoscapular amputation had been contemplated elsewhere. On July 9 1952, the patient was admitted to the hospital, and a scapulectomy was performed in accordance with the technic described previously Figure 3 D shows the head of the humerus in close proximity and immediately under the clavicle. By means of the deltoid muscle and the pectoralis major muscle this patient is able to stabilize the head of the humerus firmly against the thoracic cage and is able to use the arm the wrist and the hand to great advantage The patient does not have the dragging sensation in the region of the shoulder and the neck that was noted in the first case of this series. This patient was examined in May 1954 no local recurrence was discernible and the general health was excellent.

Case 3 R. B (Fig. 4) This is an unusual case because of the rarity of the lesion encountered. This is a desmoid tumor which originated in the infraspinatus muscle and finally implicated all the dorsal musculature of the scapula, necessitating scapulectomy This case has been reported by J B Carty in the *American Journal of Surgery* February 1954 as a case of desmoid tumor of the scapular region

Case R B., aged 24 was seen first by the author on February 25 1954 at the request of her surgeon According to the history obtained this patient had first noticed a small mass at the inferior angle of the left scapula in April 1949 the mass produced considerable pain and discomfort. On April 27 1949 resection of the inferior angle of the scapula, including the tumor and the attached muscles, was performed Because the histologic examination of a frozen section suggested a spindle-cell sarcoma a large portion of the infraspinatus portion of the scapula was excised, and wide resection of the surrounding muscles was performed Further study of the tissue removed revealed the true nature of the neoplasm its cytologic pattern was consistent with a desmoid tumor

The patient was free of symptoms for 2 years when a small painful mass was noted on the lateral margin of the scapula. On May 28 1951 the nodule together with the remaining portion of the infraspinatus portion of the scapula was removed Histologic studies disclosed that the desmoid tumor had recurred A second recurrence was noted in August 1953 this was confirmed by study of tissue removed from the old operative site The patient was treated by irradiation but no cure was effected

Examination of the patient by the author on February 25 1954 disclosed a relatively free range of motion abduction was possible to about 90 However pressure made along the anterior the inferior and the posterior aspects of the neck of the scapula elicited severe tenderness A survey of the roentgenograms at this time disclosed no evidence of implication of the stump of the scapula. A total excision of the scapula and the surrounding musculature was advised and performed according to the technic described above At operation the shoulder joint per se was inspected thoroughly and it was noted that the tumor mass had not penetrated the joint capsule The wound healed by first intention When last examined approximately 6 months following operation, the patient had an unusually good stability of the newly constructed shoulder girdle She was able to stabilize the upper end of the humerus firmly against the inferior surface of the distal end of the clavicle and the thorax and to use the lower arm with great ease This patient does not have the dragging sensation so often experienced by patients in whom the extremity tends to gravitate to a lower position and cause stretching of the

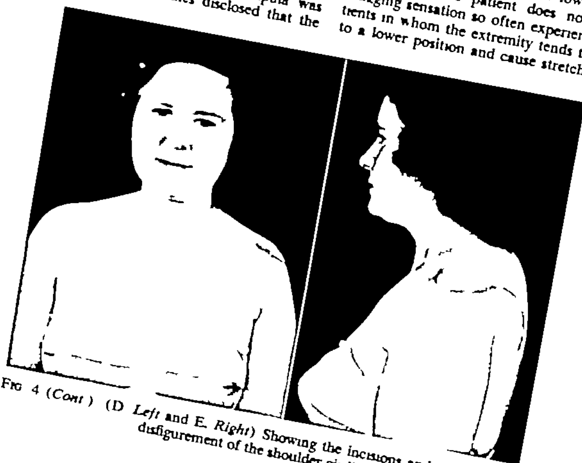


FIG 4 (*Cont*) (D *Left* and E. *Right*) Showing the incisions and the minimal disfigurement of the shoulder girdle

neurovascular structures and the soft tissues of the neck The author fully realizes that this case is too recent to know whether or not the patient will get a recurrence of the lesion in the tissues about the shoulder girdle However it does emphasize the fact that the technic of scapulectomy described is to be preferred over those technics which fail to stabilize the head of the humerus

SUMMARY

A plea has been made to employ scapulectomy more frequently in the properly indicated cases In addition to destructive lesions such as osteomyelitis and tuberculosis this technic may be used in cases of chondromas osteochondromas and endotheliomas also in cases of chondrosarcomas and even in frankly malignant sarcomas, provided that all of the implicated tissue can be removed.

A technic has been described which anchors the humeral head to the inferior surface of the clavicle and stabilizes the head of the humerus firmly against the thoracic cage and the undersurface of the clavicle this method precludes symptoms incident to stretching of the neurovascular structures and the tissues of the neck following scapulectomies without anchorage of the head of the humerus. It is the author's opinion that unless the clavicle is implicated, it should be preserved this minimizes disfigurement of the patient and functional loss of the shoulder girdle

BIBLIOGRAPHY

Brunschwig, A Excision of large desmoid tumor of pelvic outlet necessitating oblation of right levator ani muscle New York State J Med 50 1005 1006 1950

Carty J B Desmoid tumor of the scapular region Am J Surg 87 285 287 1945

Coley B L. Conservative surgery in tumors of bone South. Surgeon 10 379 1941

——— Neoplasms of Bone New York, Hoeber 1949

Ewing J Neoplastic Disease ed. 4 Philadelphia, Saunders 1941

Geschickter C. F., and Lewis, D Tumors of connective tissue Am. J Cancer 25 630-655 1935

Montgomery E. E., and Bland, P B Large desmoid tumor of the abdominal wall, Am. Medicine 10.563 Philadelphia, 1905

Musgrove J E., and McDonald, J R. Extra abdominal desmoid tumors their differential diagnosis and treatment, Arch. Path. 45 513 540 1948

Pack, G T., and Ehrlich, H E. Neoplasms of anterior abdominal wall with special consideration of desmoid tumors experience with 391 cases and collective review of literature Surg Gynec. & Obst. 79-177 194 1944

Penick, R. M Desmoid tumors developing in operative scars, Internat. Surgical Digest 23 325 329 1937

Pfeiffer C. Die Desmoide der Bauchdecken und ihre Prognose Beitr klin Chir 44 334-901 1904

Stewart, M J., and Mouat, T B Fibroma of abdominal wall Brit. J Surg 12-355 377 1924

Wiper T B and Miller J M. Desmoid of anterior chest wall Am J Surg 71.566-577 1946

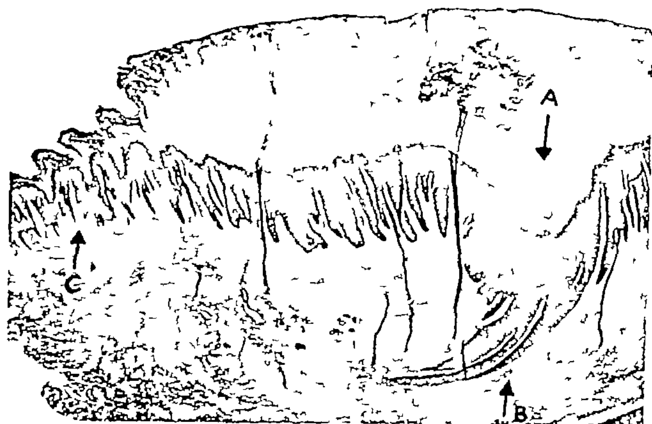


FIG 1 (A) V-shaped indentation of epidermis which is the plantar keratosis. (B) Hypertrophied rete pegs directly under the keratosis. (C) Normal epidermis and rete pegs.

treatments including excision and even in instances where skin grafts have been attempted with the consequent prolonged periods of disability and hospitalization This condition is an extremely painful and disabling one and many a patient is almost desperate in his or her attempt to secure alleviation from the pain Furthermore Dame Fashion in her decree for high heeled so-called shoes for the female sex has materially helped to increase the occurrence of the plantar keratosis which in turn accounts for the greater prevalence of this condition in the female

The average orthopaedist sees many a patient with this condition. The majority of the latter have gone through the gamut of x ray therapy and sometimes too much of it electrical fulguration application of special metatarsal pads and concentrated acids and even surgical excision but with recurrence after each form of treatment. What then is the next step? With this in mind the author several years ago attempted resection of the metatarsal head overlying the plantar keratosis The results were satisfactory from the standpoint of the relief of pain but the invariable development of the cock up or hammer deformity of the related toe with its consequent attending dissatisfaction on the part of the patient soon placed this operative procedure into the discard pile At approximately the same time Dr R. T McElvenny[1] evolved the idea of resecting the plantar half of the metatarsal head but when he reviewed the end results of this procedure he found a sufficient number of recurrences to cause him to discard it In January 1951 Dr Duncan McKeever[2] first mentioned metatarsal shortening for the treatment of plantar keratosis and subsequently published this method of therapy He recommended that the shortening be performed at the junction of the head and the neck of the metatarsal This procedure was tried and was found to work satisfac

torily except for the fact that the metatarso-phalangeal joint became limited in motion However from this idea of shortening was developed the regimen which is about to be described it has proved to be highly satisfactory Twenty-one feet have been operated upon in 20 patients The maximum follow-up study is 3 years and the minimum is six months In all but 2 patients not only has the plantar keratosis disappeared spontaneously and the foot become asymptomatic in each instance but also no keratoses have developed under any of the adjacent metatarsal heads and no foot imbalance has developed. In the 2 patients in whom the plantar keratosis recurred careful analysis has revealed that the metatarsal shaft was not shortened sufficiently

A short résumé of each case is presented in order that the reader may have the opportunity to evaluate the results herein reported

CASE STUDIES

S B — Nurse

The patient was seen on 3 2 51 complaining of pain under the right fourth metatarsal head where upon examination, a plantar keratosis was found, which had been present for the past 8 months. She had had one series of 6 x-ray treatments and had worn a metatarsal pad with no improvement of her symptomatology On 3-6-51 shortening of the fourth metatarsal shaft was carried out at the base Follow-up examination on 5 15 54 revealed complete disappearance of the plantar keratosis. The foot is entirely asymptomatic and she has returned to her occupation as assistant head nurse on a busy surgical floor

A B — Housewife

The patient was initially seen on 7 16-51 and examination revealed the presence of a plantar keratosis under the left fourth metatarsal head. The past history revealed that this keratosis had been excised in June 1950 It had reccurred by September 1950 at which time one series of x ray therapy was administered. The plantar keratosis again recurred within 3 months, and in December 1950 a second series of x-ray therapy was given The patient suffered with this plantar keratosis for 2½ years. Surgery was performed on 7 9 51 consisting of shortening of the fourth metatarsal. Follow-up examination on 6-1 54 revealed that the keratosis had disappeared entirely and the patient's foot was asymptomatic

E. I — Housewife

The patient was initially seen on 2 16-52 Examination revealed the presence of a plantar keratosis under the third metatarsal head of the right foot with severe scarring of the surrounding soft tissues. The patient had had this plantar keratosis for years She had had two courses of x-ray therapy radium insertion, dry ice and metatarsal pads with no relief of her pain and discomfort. On 3 14-52 shortening of the third metatarsal shaft was performed. Follow up examination on 5 2 54 revealed the recurrence of the plantar keratosis. Although the patient still has some discomfort with this foot, she stated that the pain is not as severe as it was prior to the shortening of this metatarsal Apparently with the shortening, sufficient pressure has been removed from the plantar aspect of the metatarsal head to produce less pain. However this case must be considered as a failure since recurrence of the plantar keratosis has recurred

C C — Machinist

The patient was seen initially on 2 16-52 demonstrating 2 plantar keratoses located under the left third metatarsal head which had been in existence for the past 6 years. The patient had had x-ray therapy metatarsal pads and finally a block excision and skin graft on 12 10-48 with recurrence of the plantar keratosis. On 3-7 52 shortening of the third metatarsal shaft was carried out, and final follow-up examination 3 months ago revealed the foot to be entirely asymptomatic the plantar keratosis had disappeared, and the patient is able to work as a machinist standing the entire day without the necessity of a metatarsal pad.

D R. — Nurse

The patient was seen initially on 11 13-51 presenting a plantar keratosis under the left third metatarsal head and also a plantar keratosis under the right third metatarsal head and under the right medial sesamoid bone She had undergone x-ray therapy application to dry ice and repeated trimming as well as metatarsal pads with no relief of her symptomatology On 3-4-52 shortening of the left third metatarsal head was carried out. On 12 2 52 shortening of the third metatarsal head of the right foot and excision of the medial sesamoid bone was performed. Follow-up examination on 11-4-53 revealed that the plantar keratoses had disappeared under both metatarsal heads and under the area where the medial sesamoid was located. Although the patient demonstrated callus for

mation under the other metatarsal heads of both feet since her feet are rather thin, there is no callus formation present under the third meta tarsal head of either foot.

L. A — Housewife

The patient was seen initially on 4-9-47 and demonstrated plantar keratosis under the right fifth metatarsal head and under the medial sesamoid The patient had undergone treatment for the previous 3 years consisting of x ray therapy fulguration with dry ice application of metatarsal pads and trimming. The patient was unwilling to consider surgery and comma shaped pads were prescribed. On 5 12 52 resection of the fifth metatarsal head and excision of the medial sesamoid was performed since the patient was unwilling to continue having as much pain as she did Follow-up examination in April 1954 revealed that the plantar kera toses had disappeared entirely and the foot is asymptomatic. However a metatarsal pad is still worn because of the resection of the fifth metatarsal.

S I — Housewife

The patient was seen initially on 4-30-47 and demonstrated the presence of a plantar keratosis under the left third metatarsal head. For the 5 years prior to surgery the patient had had x-ray therapy with recurrence of the plantar keratosis, application of dry ice with the same recurrence, and subsequent to that, trimming of the kera tosis and the application of a metatarsal pad On 7 22 52 shortening of the third metatarsal shaft was carried out, and follow-up examina tion in March, 1954 revealed the plantar kera tosis to have disappeared and the foot to have been entirely asymptomatic The metatarsal pad was also discarded

M M — Nurse

The patient was seen on 7 22 52 and exami nation revealed plantar keratosis under the right second metatarsal head which had been present for one year The patient had had no treatment except for trimming of the keratosis. On 7 23-52, shortening of the second metatarsal head was carried out Within 4 weeks following surgery the patient returned to duty as a nurse and there has been complete disappearance of the plantar keratosis and no symptomatology referable to the foot.

M S — Housewife

The patient was seen initially on 9 24-51 and presented a plantar keratosis under the right second metatarsal head with hammer toe de formity of the right second toe The keratosis had been in existence for 4 years and had been controlled by trimming. On 10-3 52 shortening of the second metatarsal head with resection of the proximal one half of the proximal phalanx was performed, since the second metatarso-phalangeal joint was dislocated prior to opera tion Follow-up examination in March, 1954 revealed the foot to be entirely asymptomatic. The plantar keratoses have disappeared

S B — Milkman

The patient was seen initially on 7 28 52 pre senting an infected plantar keratosis under the left third metatarsal head which had been present for 8 years The patient had undergone x-ray therapy had had 2 excisions of the plantar kera tosis with recurrence and subsequent unsuc cessful electrocautery On 11 10-52, shortening of the third metatarsal head was performed. The foot was asymptomatic within a period of 4 weeks. The patient was able to return to work as a milkman on his regular route Follow-up examination in February 1954 revealed the foot to be entirely asymptomatic. The plantar keratosis has disappeared, and the scar tissue from the previous surgery is minimal

M R —Nurse

The patient was seen on 9 26-52 at which time a plantar keratosis was found under the left third metatarsal head This had been present for the past 6 months. The patient had had one series of x ray treatments with recurrence of the plantar keratosis since then the patient had maintained comfort by trimming and applica tion of a metatarsal pad. On 12 26-52 shorten ing of the third metatarsal was performed, and the patient was able to return to work in a walk ing cast. Follow-up examination in April 1954 revealed the plantar keratosis to have recurred but the patient's symptomatology is not as severe as it was preoperatively In this case it is felt that the shaft was not adequately shortened and therefore this case should be considered as a failure.

E. G — Saleslady

The patient was seen initially on 11 24-52, and upon examination an ulcerating, infected plantar keratosis was found under the right sec ond metatarsal head which had been present for the past 3 years The patient had had excessive x ray therapy as estimated from the number of x-ray treatments she was given which accounted for this ulcerated infected condition On 1 2 53 shortening of the second metatarsal head was carried out. Within 6 weeks, the area was healed Within 3 months, the plantar keratosis had disappeared. Follow-up study in May 1954 re vealed the foot to be asymptomatic The kera

tosis had disappeared and the scar tissue on the plantar aspect of the foot was minimal. The patient's occupation requires her to stand the entire day

G E. — Housewife

The patient was seen initially on 3 11 53 demonstrating a plantar keratosis which had been in existence for 2 years under the second metatarsal head of the left foot. The previous treatment consisted of excision of the plantar keratosis with recurrence and subsequent application of the metatarsal pad. On 3 23 53 shortening of the second metatarsal was performed The patient's foot is asymptomatic although the plantar keratosis is still present as a very small nidus

J T — Student

The patient was examined on 5 12 53 presenting a plantar keratosis under the third metatarsal head of the right foot which had been present for several months Previous treatment consisted of the application of Formalin with Aquaphor and also with trimming of the plantar keratosis with no improvement. On 6-16-53 shortening of the third metatarsal head was carried out. When examined on 9 14-53 the patient's foot was asymptomatic the plantar keratosis had disappeared, and the patient was playing football. Follow-up examination in April 1954 revealed the foot to be asymptomatic with the plantar keratosis having disappeared completely

E. H. — Housewife

The patient was seen initially on 5 9-53 presenting a plantar keratosis under the right medial sesamoid which had been present for 12 years and had been treated with metatarsal pads and trimming. On 7 7 53 excision of the medial sesamoid was performed. Examination in March 1954 revealed the foot to be asymptomatic and the plantar keratosis to have disappeared

E F — Housewife

The patient was examined initially on 6-26-53 demonstrating a plantar keratosis under the left second metatarsal head which had been present for the past 20 years and had been treated simply by trimming and wearing comfortable shoes. On 7 21 53 shortening of the metatarsal head was carried out. When last examined in March 1954 the patient was able to wear high-heeled shoes for the first time in many years, and examination revealed the plantar keratosis to have disappeared and the foot to be asymptomatic

M C — Housewife

The patient was seen initially on 9 19 50 At this time she presented a nest of 3 plantar keratoses which appeared to be located between the second and the third metatarsal heads. She was treated conservatively with trimming and metatarsal pads for 3 years at the end of which time she requested that surgery be performed Standing marker x rays revealed the plantar keratoses to be under the second metatarsal head. Accordingly shortening of the second metatarsal was performed on 10-15 53 Follow-up examination in May 1954 revealed the plantar keratoses to have disappeared and the foot to be entirely asymptomatic

M M — Nurse

The patient was seen initially on 6-30-53 complaining of pain under the left third metatarsal head where upon examination a plantar keratosis was found For the previous 6 months the patient had maintained comfort by trimming the plantar keratosis but finally decided that she wished surgery to be performed On 11 30-53 shortening of the third metatarsal was carried out. The patient returned to her nursing duties in a walking cast at the end of 10 days. Follow-up examination in June 1954 revealed the plantar keratosis to have disappeared entirely and the foot to be asymptomatic with the patient being able to work at full 8-hours duty without any difficulty or any special shoes.

G F — Laborer

The patient was seen on 11-4-53 because of a plantar keratosis under the right second metatarsal head which had been present for 18 months. The treatment had consisted of wearing a metatarsal pad and trimming of the plantar keratosis On 12 10-53 shortening of the second metatarsal was carried out. Follow-up examination in May 1954 revealed the plantar keratosis to have disappeared entirely The foot was asymptomatic The patient's occupation is such that he stands on concrete the entire day without any difficulty

K. W — Housewife

The patient was seen initially on 11 2 53 with an infected plantar keratosis under the left second metatarsal head. This had been present for the past 3 years. The patient was also a mild diabetic controlled only by diet. On 12 10-53 shortening of the second metatarsal was carried out. Within 4 weeks draining had subsided and the area had healed On follow-up examination in May 1954 the plantar keratosis had disappeared There was a small amount of scar tissue due to the previous infection, but the foot was asymptomatic and the patient was able to walk without any difficulty

REGIMEN OF TREATMENT

Following examination of the foot, standing roentgenograms are ordered in the AP position with a small lead marker directly over the plantar keratosis in order to determine the exact location of the plantar keratosis in relationship to the overlying metatarsal head. If the lesion is not directly under the metatarsal head or under the medial or lateral sesamoid of the first metatarsal, this surgical procedure is not recommended, since it will be doomed to failure. The operation consists of shortening of the metatarsal shaft. It is performed under tourniquet ischemia at the base of the metatarsal, since there is more cancellous bone at this level and therefore callus formation and healing will occur more rapidly.

The incision is made on the dorsum of the foot over the corresponding metatarsal beginning at approximately the mid-shaft level and extending proximally to the tarsometatarsal joint. The small muscles are reflected subperiosteally. With a $\frac{1}{16}$-inch wide drill point inserted in a small hand drill, a series of drill holes are made and a 1 inch step cut is outlined (Fig. 2A). A thin ½ inch wide osteotome is used to complete the step cut. Upon completion of the osteotomy ½ an inch of each tongue of the step cut is rongeured carefully, thus producing a ½ inch shortening of the metatarsal shaft (Fig. 2B). A drill hole is made through each cortex of the remaining portion of the tongue so that a No. 2 chromic catgut suture may be passed through each hole and upon tying the suture the defect will be closed, and the two bone ends will be held in the shortened position (Fig. 2C). Following closure of the soft tissues, a firm Schantz dressing is applied. This is maintained on the foot for 3 to 4 days at the end of which time a plaster of Paris walking boot is applied, extending from the tips of the toes to the mid-leg. The toes are placed in a position of moderate plantar flexion at the metatarso-

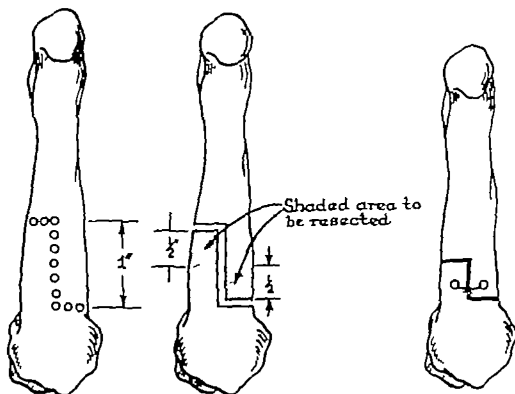


Fig. 2. (*Left*) Drill holes outlining step cut. (*Center*) Osteotomy completed and portion of each tongue to be resected. (*Right*) Shortened metatarsal.



FIG 3 (*Top left*) Plantar keratosis preoperative appearance on May 12, 1953 (*Top right*) Same area, postoperative appearance on March 27 1954 (*Bottom left*) Fungating infected plantar keratosis, preoperative appearance on Nov 24 1952. (*Bottom right*) The same area on June 9 1953—7½ months postoperatively Since then slightly hyperkeratotic area has disappeared.

phalangeal joint level The patient becomes ambulatory within 24 hours after the application of the cast. The amount of discomfort upon initial weight-bearing is surprisingly mild The patient is not only encouraged but also advised to be up and about as much as possible and even to return to work. The cast is removed at the end of 4 weeks after its application. No metatarsal pad is applied to the foot upon removal of the cast.

Fig. 3 represents preoperative photographs of plantar keratoses and subsequent photographs taken several months following operation As can be seen, the keratosis in each instance has disappeared spontaneously

CONCLUSION

The diagnostic term plantar keratosis and not plantar wart, should be used when the above-described condition is found.

Shortening of the metatarsal shaft has been successful in correcting this entity in 19 out of 21 cases In 2 instances the keratosis recurred a failure rate of 9 5% In both of these recurrences the shaft was not shortened sufficiently However neither patient has as much pain as she had previously

REFERENCES

1 McElvenny R T Personal communication
2. McKeever D C. Arthrodesis of the first metatarso-phalangeal joint for hallux valgus, hallux rigidus, and metatarsus primus varus J Bone & Joint Surg 34 A 129 1952.

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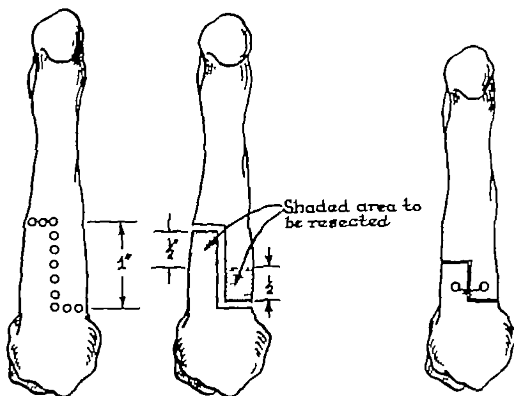


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